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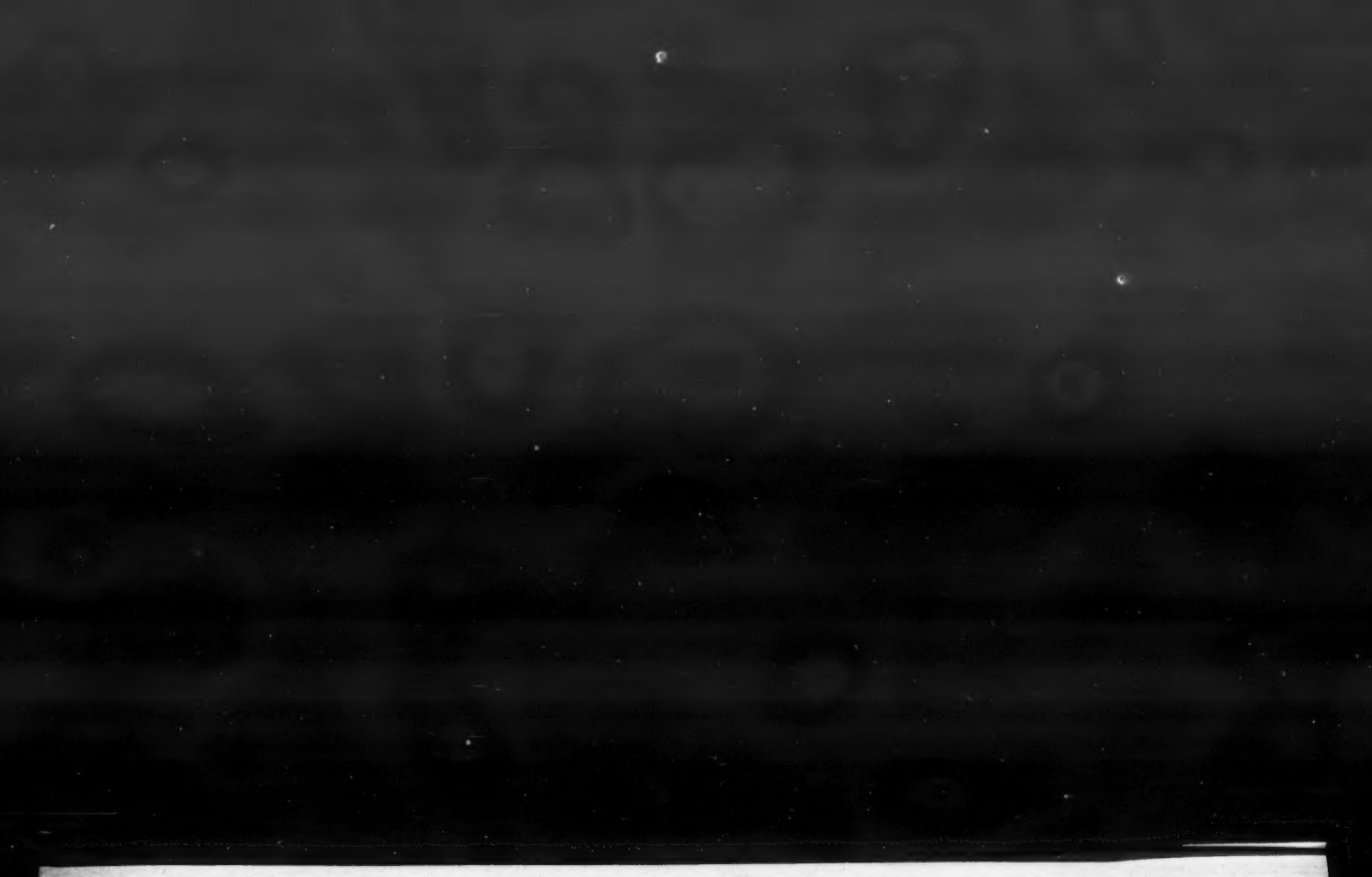


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXII.—*Geothermal Data from Deep Artesian Wells in the Dakotas;* by N. H. DARTON, U. S. Geological Survey.*

THIS paper is intended to set forth new facts as to the underground temperature of a portion of eastern South Dakota and North Dakota, derived from records of temperatures of waters flowing in large volume from nearly level strata lying from 500 to 1500 feet below the surface. These temperatures are found to be exceptionally high over a wide area, but present regular regional variations. The salient features are shown in figure 1, p. 163.

Nearly all the waters in the great artesian basin of the Dakotas are perceptibly warm,—some are notably so,—but as they are derived from a considerable depth, no attention has been paid heretofore to the geothermal rates which the high temperatures indicate. In the course of several investigations which have been made in the artesian basin, temperatures of many of the flows have been observed, some with great care. The highest temperature recorded is at Harold, in Hughes County, where the flow is stated to be 94·9° F. At Pierre the water has a temperature of 92° F. and supplies a fine swimming pool at the sanitarium. At some other localities in the Missouri valley the temperatures of flows are as follows:

Cheyenne Agency	79° F.
Crow Creek Agency	72° F.
Chamberlain	70° to 71·6° F.
Fort Randall	80° F.
Greenwood	70° F.
Yankton	60° to 64° F.

* Published by permission of the Director of the U. S. Geological Survey. Read at Montreal meeting of the Geological Society of America, December, 1897.

In James River valley the greater number of flows range in temperature from 65° F. to 70° F., and the principal wells vary in depth from 550 to 1500 feet. The flows are usually several hundred gallons per minute, in many cases from 1000 to 2000 gallons and in a few instances from 3000 to 4000 gallons per minute.

The water-bearing horizon is the Dakota sandstone, which lies upon crystalline rocks and beneath a thick mass of Upper Cretaceous shales and chalk. The beds lie nearly horizontal or in an irregular, very flat-bottomed synclinal.*

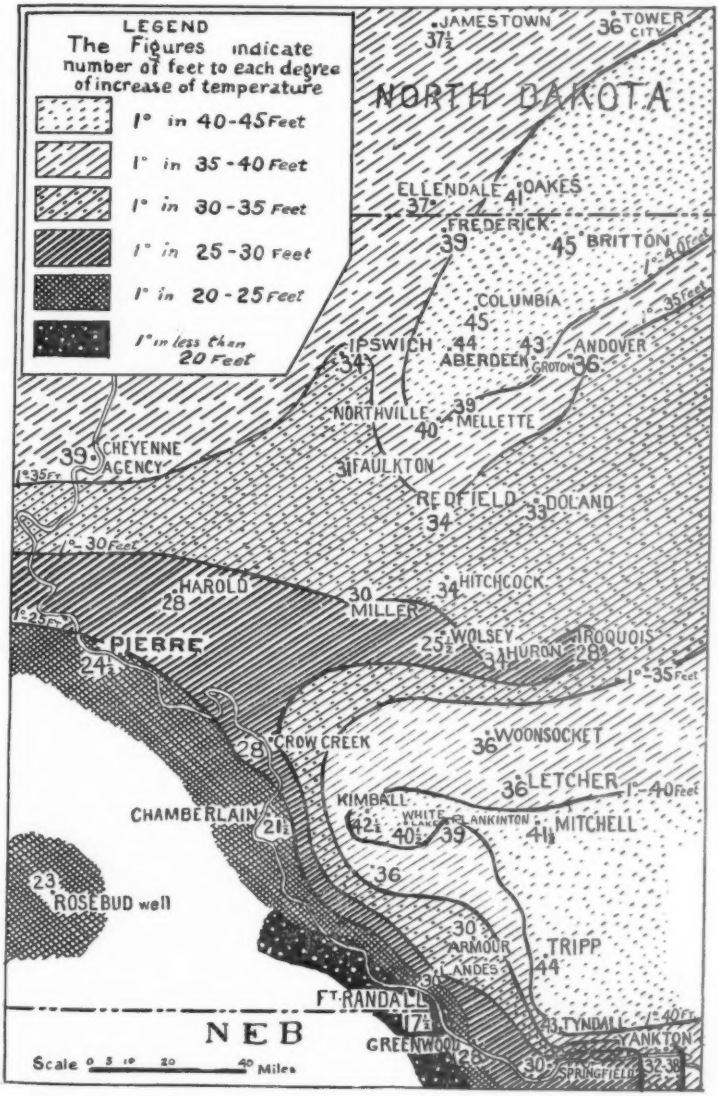
As the waters from the wells selected flow in large volume and have been flowing for some time, their temperature at the surface is practically the same as that of the underground stratum from which they rise. As the depth of the water-bearing stratum is known in every case, it has been a simple matter to calculate the rate of temperature-increase. In many parts of the world it has been found that the rate of increase of temperature averages about one degree for each 50 feet, below the first 40 feet, in which the temperature is usually regarded as that of the mean annual temperature of the region. In the greater part of the artesian basin of the Dakotas the rate of increase is found to be greatly more than this, attaining at Fort Randall a rate of one degree for each 17½ feet. At this well the temperature of the water is 80° F., or possibly slightly more, but the depth from which it is derived is only 576 feet, which indicates the abnormally high rate of increase. At Chamberlain, a rate of one degree for 21½ feet is indicated, and at Pierre one degree for 24½ feet. To the north and east these amounts diminish, but over a wide area the amount of increase is one degree for every 25 to 35 feet. The records of temperatures, which I have been able to obtain, are scattered widely over the artesian basin, so as to afford a very definite idea as to the areal distribution of the underground temperatures. They are principally derived from two observers: Prof. J. H. Shepard of the U. S. Experiment Station at Brookings, South Dakota,† and Col. E. S. Nettleton's report‡ on "Artesian and Underflow Investigation" for the Department of Agriculture. The data are given in the table on page 164.

* A description of the geology and resources of the basin may be found in the paper entitled "Preliminary Report of Artesian Waters in a portion of the Dakotas," by N. H. Darton, 17th Annual Rep. U. S. Geol. Survey, 1895–96, Part II, pp. 1–92, Pl. LXIX–CVII, Washington, 1896.

† South Dakota Agricultural College, etc.; Bull., xli, November, 1894, 35 pp.

‡ Sen. Ex. Doc., No. 41, 52d Congress, 1st Sess., Part IV, Washington, 1893.

1.



Map showing rates of increase of underground temperatures in deep wells in Eastern South Dakota and North Dakota, by N. H. Darton.

Table of Data bearing on Artesian Well Temperatures in the Dakotas.

Locality.	Depth of bed yielding the water.	Temperature of flow.	Flow per minute.	Mean annual temp.	Rate of temperature increase for 1° F.
	Feet.	F.	Gallons.	F.	Feet.
Aberdeen, City well No. 1	1077–1100	66·9° *s*	400	42°	44
Andover	1070–1075	71·6° *s*	300	42	36
Armour	696– 757	68·3° *s*	1500	44	30
Britton	976–1000	64° *n*	600	42	45
Chamberlain, Mill	585– 600	71·6° *s*	4000	45	21½
" 25 miles S.E.	851– 937	70°	1098	45	36
Cheyenne Agency	1337	79°	500	45	39
Crow Creek	760– 780	72°	Many	45	28
Columbia	927– 964	63° *n*	940	42	45
Doland	880– 895	69·05° *s*	370	42	33
Ellendale	1042–1087	69° *n*	700	40	37
Fort Randall	576	80° *n*	600	47	17½
Frederick	1045–1139	69° *n*	135	41	39
Faulkton	1032?	74·5° *s*	100	42	30⅔
Greenwood	641– 651	70°	3000	47	28
Groton, 4 miles north	840– 942	63° *n*	150	42	43
Harold	1435–1451	94·9° *s*	84	43	28
Hitchcock	950– 953	70·1° *s*	1260	42	34
Huron	960	70°	2250	42	34
	836	65°	360	42	36
Ipswich	1000?	71·6° *s*	Many	42	34
Iroquois	850– 855	71·4° *s*	1000	42	29
Jamestown	1458–1476	76° *n*	460	37	37½
Kimball	988–1068	66·9° *s*	185	43	42½
Lake Andes	725– 773	70°	1500	45	30
Letcher	570– 577	58° *n*	80	42	36
Mellette	884– 920	65° *n*	1320	42	39
Miller	1115–1139	79·8° *s*	363	42	30
Mitchell	530– 548	56° *n*		43	41½
Northville	958– 980	66·1° *s*	1900	42	40
Oakes	937	62° *n*	817	39	41
Pierre	1150–1170	91·8° *s*	900	45	24½
Plankinton	740– 745	62° *n*	225	43	39
Redfield	944– 964	70·1° *s*	1260	42	34
Rosebud Reservation	2500	153½°	No.	46	23½
Springfield	530– 592	65° *n*	3292	46	29
Tripp	? – 815	63°	700	45	44
Tyndall	700– 735	62·6° *s*	1000	46	43
White Lake	842– 850	64° *n*	150	43	40½
Wolsey	858– 878	76° *n*	330	42	25½
Woonsocket	684– 725	61·5° *s*	1150	42	36
Yankton	489– 595	62° *n*	1450	46	34
	432– 455	60° *n*	330	46	32
	610– 615	62° *n*	880	46	38
	600– 672	64° *n*	165	46	35
" Cement works, 4 miles west	450– 500	64° *n*	1300	46	26½

In this table the observations given by Prof. Shepard are marked *s*, and they are, I believe, very accurate. The temperatures marked *n* are by Col. Nettleton. They are approximate but appear to accord very satisfactorily. The figures for the Huron wells were given by the well owners; the Cheyenne Agency, Crow Creek and Greenwood wells were reported by

the United States Indian Agents at these points; the well 25 miles southeast of Chamberlain is on the authority of the well driller, Mr. Kaufman, and the well at Tripp is stated by the chairman, Mr. Hassett, of the Town Board as "about 63° F." A 2500-foot boring on the Rosebud Reservation, 65 miles southwest of Pierre, was tested by a pair of self-registering maximum thermometers, sent to its bottom by my assistant, Mr. F. H. Ainsworth. The mean annual temperatures which have been used for the comparisons are based on observations which have been made by the U. S. Signal Service as follows:*

Jamestown, North Dakota	37° F.
Huron, South Dakota	42°
Kimball "	43°
Fort Meade "	45°
Fort Randall, South Dakota	47°
Fort Sisseton, "	48°
Fort Sully, "	45°
Webster, "	43°
Valentine, Nebraska	46°
Yankton, South Dakota	46°

For the wells not very near these places I have assumed the most probable mean temperature in comparison with the nearest localities at which observations were made. It is realized that there is of course some chance for error in this procedure, but the small difference does not greatly affect the final product of calculation. It would of course have been much safer to have observed the temperature of the earth at a moderate depth at all the localities to determine the differences of temperature, but this was not practicable. In most cases it has been possible to take for the depth the middle of the water-bearing bed as far as pierced by the well. The rate of temperature-increase has been calculated from the surface down to this depth and without deducting the usual 40 feet at the surface, as has been done sometimes in making such calculations. In considering the data I have selected only wells over 400 feet in depth and yielding large flows. They are all cased from the top to the bottom. The deep well at Highmore was excluded on account of its small flow, for in this instance the water loses much of its heat before reaching the surface. The temperature of the Highmore water, however, is 72° F., according to Nettleton, the flow is 9 gallons and the source is about 1550 feet below the surface. At Aberdeen one of the earlier city wells was reported by Nettleton to yield water at a temperature of 66° F., from a depth of from 905 to 918 feet,

* "Certain Climatic Features of the two Dakotas," by J. P. Finlay (Weather Bureau), page 119, Washington, 1893.

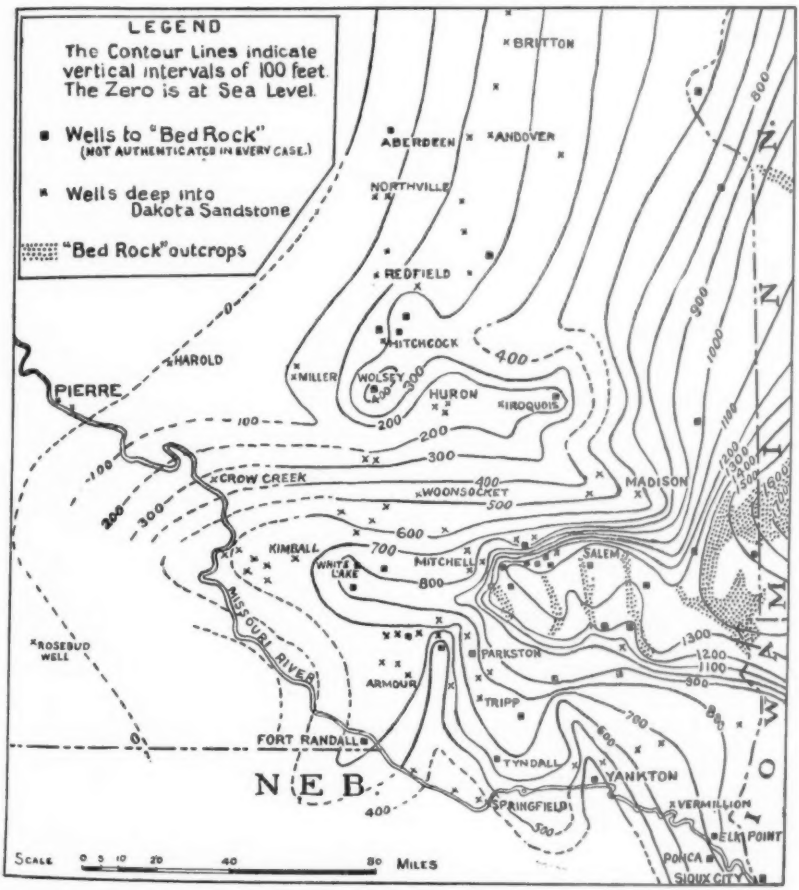
which is at the rate of 1° for each 38 feet, somewhat less than in the deeper well recorded in the table. I prefer, however, to take the figures of Professor Shepard for this deeper well, for here the conditions appear to be more definitely determined.

It will of course be obvious that where underground water is circulating rapidly in horizontal beds, it would retain the same temperature over quite a wide area under high land and low land alike, consequently, if a well were sunk on high land the rate of increase in feet to every degree would be a very much larger figure than in the adjoining low lands, where the water would be reached at much less depth. I have weighed this suggestion in the region in question, and excepting, possibly, about Tyndall, Yankton and Springfield, believe that its influence is practically nothing. It must be borne in mind in this connection that underground waters move at an extremely low rate of speed, which is probably not over a mile or two a year in the sands of the Dakota formation, and under these conditions the water of a flowing well represents very nearly the local underground temperature at the bottom of the casing of the well. The altitudes of the wells have been found to have practically nothing to do with the differences of temperatures, excepting probably where wells are quite near together. It is not fair to assume that the isogeothermal *planes*, even for moderate depths, are closely parallel to minor undulations of the surface of the ground. Consequently in a deep well on a high hill the rate of temperature-increase would be lower than in a correspondingly less deep well at the foot of the hill. The ratios in a case of this sort have not as yet been ascertained and they probably vary locally.

The difference of rate in the increase of temperature in the wells at Chamberlin is thought to be due to the relative positions of these wells. The city well with the smaller rate is some distance east of the mill well, which may account for the difference, as it is in line with the diminution eastward to 1° in 41 feet at Kimball. In the wells at Yankton the difference of actual temperatures of the waters is not great, but as the depths of the wells vary considerably the ratio of temperature-increase varies from 32 to 38 feet for each degree. It is probable that in this case the water may all come from one stratum, and if the minimum depth of this be taken, the rate of 1° for each 32 feet is obtained. In the cement works 4 miles west of Yankton an increased rate is indicated, The areal relations of the data are shown in fig. 1. As the observations are distributed at short intervals over a wide district, and the geothermal ratios vary gradually and uniformly, it has been possible to introduce isogeothermal lines in this figure. Without a knowl-

edge of the vertical gradients of temperature-increase in the individual wells, it would not be safe to attempt to calculate the temperature to a uniform depth beneath the surface, so I

2.



Contour map of "Bed Rock" surface in a portion of the Dakota Artesian Basin, by N. H. Darton.

have employed the "feet per degree" product for the "isogeotherms."

The most notable features in figure 1 are, the strip of high temperature along the Missouri River valley beginning near

Pierre and extending far to the southwest, south and southeast, and culminating at Fort Randall; the long area of moderately thermal district extending eastward along the latitude of Pierre, from Miller, Wolsey, Huron and Iroquois; the area of relatively cool underground conditions extending westward as a tongue through Mitchell, Plankinton, White Lake and Kimball, and southward towards Tyndall, and the similar oblong area extending through Britton towards Aberdeen. In considering the data it was at once observed that these features of areal distribution were closely similar to the configuration of the "bed rock" surface. Accordingly I have given, in fig. 2, a contour map of this surface for comparison. The long area of the cooler underground conditions from Mitchell to Kimball will be seen to be almost coincident with the underground ridge shown in the figure. This ridge is mainly of Sioux quartzite. The area of higher temperatures just north is approximately along the bottom of the valley in the "bed rock," which extends from Madison through Huron and south of Wolsey. Beyond these very striking features the resemblances are not noteworthy, but those above pointed out strongly suggest that the cooler area extending from Kimball to Salem is in some way related to the presence of the ridge of crystalline rock beneath the surface.

This brings us to the question of the cause of the thermal conditions in the Dakota artesian basin, but no satisfactory solution has as yet been suggested. So far as we know there are no metamorphic processes nor orogenic movements in progress in this region which would give unusual underground heat. The suggestion of the oxidation of pyrites by underground waters is probably untenable on account of the depth. Several ideas have been considered, comprising one that possibly some glacial chilling still remains in the ridge of "bed rock"; another of different ratios of conductivity, and a third, that the process of induration now probably in progress in the sediments is giving rise to heat; but many difficulties preclude their acceptance in our present state of knowledge.

This investigation is to be extended as widely as possible, and preliminary to this end I am now making a canvass of all available underground temperature observations in the United States so far as noted. I shall be very glad to receive data from geologists and others.

ART. XXIII.—*On a Series of Transition Beds from the Comanche to the Dakota Cretaceous in Southwest Kansas;* by CHARLES NEWTON GOULD.

DURING the last decade the geology of Southwest Kansas has received considerable attention. Such earnest investigators as St. John, Hay, Cragin, Williston, Hill, Haworth, Prosser, Vaughan and Ward, by their published articles have made this region familiar to American geologists. Probably the most exhaustive report is that of Professor Prosser.* To his excellent review of the literature the reader is referred.†

The Cretaceous of the region is conformable throughout and everywhere rests unconformably on the eroded surface of the subjacent Triassic (?) Red Beds and is covered by the Tertiary or by the Pleistocene. It begins near Sun City in northwestern Barber county, and gradually thickens westerly, attaining its maximum on the upper Medicine river west of Belvidere. It thins out to a mere line at Coldwater, again thickens on Bluff, Bear and Sand creeks in Clark county and finally disappears at the Big Basin in the western part of the county. As stated by Professor Prosser,‡ the lower part of the Cretaceous—consisting of two formations, the Cheyenne sandstone and the Kiowa shales,§—undoubtedly belongs to the Comanche Series.

The Cheyenne sandstone is composed mainly of coarse-grained, friable, false-bedded sandstone. Its color is normally yellowish or gray with streaks and blotches of red, pink, brown or black. The lower part contains many smooth, water-worn pebbles and occasional lenticular masses of bluish clay, while the upper part consists of alternating layers of sandy shale and more or less argillaceous sandstone, containing much lignite and a most interesting flora, consisting of ferns, conifers, dicotyledons, etc. No animal fossils have been found. The maximum thickness is probably between 50 and 60 feet.

The Kiowa shales, which lie on the Cheyenne, consist of bluish-black to yellowish papyraceous shales with numerous layers of limestone, containing great numbers of marine invertebrates. In the lower part of the shales are found vertebrates and insect remains. The maximum thickness reported by Prosser is 140 feet.

The presence of Dakota-like sandstone in both the Belvi-

* University Geological Survey of Kansas, vol. ii, 1896, pp 55–194.
† Ibid., pp. 96–111. ‡ Ibid., p. 111.
§ These names were first used by Professor Cragin. See Bulletin Washburn College Laboratory of Natural History, vol. ii, December, 1889, p. 65, and Colorado College Studies, vol. v, April, 1893, p. 49.

dere and Clark county regions has been noticed by nearly every geologist who has visited the localities. Professor Cragin says:* "The actual contact of the Dakota series upon the Fredericksburg division" (Comanche) "is well shown in the heads of Bear creek and Little Sandy in Clark county. . . . At the Blue Cut hill S.S.W. of Belvidere in Kiowa county and on many high points in this and neighboring counties bowlder-remnants of the Dakota sandstone overlie the Fredericksburg shales." In the upper West Bear creek section he mentions 40 feet of "dark brown to yellow Dakota sandstone containing meager fragments of dicotyledonous leaves."† Professor Cragin afterwards refers to the "leaf-bearing *Reeder* (Dakota?) sandstone which surmounts the Kiowa shales in the upper valley of the Medicine Lodge river near the post-office at Reeder."‡ And again, in speaking of the Tucumcarri shales (the upper member of the Kiowa) says:§ "At their summit they frequently contain bands and concretions of clay-ironstone, in the succession of which, premonitory of the immense aggregation of concretions that constitute certain parts of the Reeder sandstone of Kiowa and Clark counties, the Gryphæa, now in its maximum size, is lost sight of, becoming scarcer and more poorly preserved before wholly disappearing."

Professor Hill describes the Dakota on Blue Cut Hill.‖

Professor Prosser mentions the occurrence of "Dakota" sandstone in various localities¶ and describes apparent contact with the underlying Kiowa on upper West Bear creek (Cragin's locality) and assigns to the Dakota at this place a thickness of 75 feet.**

The writer has spent a good part of four summers in the region, having worked with Dr. Williston and Professor Hill in 1894, in the employ of Johns Hopkins University in 1895, with Professor Prosser in 1896, and with Dr. Williston and Dr. Ward in 1897. It was while acting as a member of Dr. Ward's party that the Transition Beds, which form the title of this article, were discovered.††

Of the following sections Nos. I, II and III were made on Greenleaf's and Kirby's ranches on the upper Medicine river some ten or twelve miles west of Belvidere, and twelve miles south of Greensburg, Kiowa county, Kansas, while Nos. IV and V were taken on Little Sand and Chatman creeks twelve miles northwest of Ashland, Clark county, Kansas.

* Bulletin Washburn College Laboratory Natural History, vol. ii, March, 1890, p. 74.

† Ibid., p. 77.

‡ American Geologist, vol. xvi, December, 1895, p. 381. § Ibid., p. 382.

‖ This Journal, vol. l, September, 1895, p. 210.

¶ Loc. cit., p. 118. ** Ibid., pp. 162–164.

†† Science, N. S., vol. vi, Nov. 26, 1897, pp. 814, 815.

SECTION I.

½ mile south of Greenleaf's ranch.

No.		Feet.
3.	Small Tertiary knob resting unconformably on No. 2	15–95
2.	Bluish clay shales, weathering white, containing numerous clay-ironstone, geodic, concretions, breaking with a conchoidal fracture into small fragments with sharp edges. One stratum of brown sandstone 4 inches thick contains marine bivalves and shows ripple marks on its surface. The clays contain layers of sandy shales in the upper part. The Spring Creek clays	50–80
1.	Typical upper Kiowa bluish-black to yellowish shales with selenite crystals and numerous Gryphaea, grading insensibly into No. 2	30–30

SECTION II.

½ mile west of Greenleaf's ranch.

4.	Tertiary sandstone on top of bluff	10–90
3.	Yellowish brown sandstone, usually distinctly stratified, but occasionally massive and cross-bedded, containing bands and concretionary pockets of dark brown or black clay-ironstone, breaking with a conchoidal fracture; eroded in upper part. The Greenleaf sandstone	40–80
2.	Bluish-white clay with clay-ironstone concretions. Slope mostly covered. The Spring Creek clays	20–70
1.	Black to bluish Kiowa shale to bed of river, with occasional Gryphæa. Slope usually covered	20–20

SECTION III.

On Spring Creek, 1 mile south of the Kirby (or C. W.) ranch.

No.		Feet.
6.	Tertiary slope to top of divide	50–200
5.	Dark brown massive sandstone, often cross-bedded, with many white pebbles and large nodular concretions, which sometimes attain the size of 2×3 feet. No fossils noticed. The Reeder sandstone	20–150
4.	Yellowish clays, arenaceous below, becoming reddish above and containing several strata of light yellow sandstone. The characteristic fragments of clay-ironstone color the slopes. The Kirby clays	20–130
3.	Light gray to yellowish sandstone often distinctly stratified but sometimes cross-bedded and massive with bands and pockets of the characteristic dark brown or black clay-ironstones. The Greenleaf sandstone	55–110
2.	(*c*) Yellowish to bluish clays, weathering white, containing, in lower part, bands of spongy clay-ironstone like (*b*), which weather into small, irregular, pinkish lumps and give a red tint to the slopes	20

No.		Feet.
	(*b*) Dark brown to yellow, rough, spongy clay-ironstone with bands and pockets of clay, weathering into conspicuous buttresses. It is occasionally concretionary or undulatingly stratified, and in places disappears	5
	(*a*) Shales and clays, greenish to yellow, containing many strata of gray shaly sandstone 1 to 8 inches thick. The clay contains many reddish-brown clay-ironstone concretions often geodic and containing clay. On weathering these break with a conchoidal fracture, often forming round or angular, cup-shaped fragments with sharp edges	15
	(*a*), (*b*) and (*c*) form the Spring Creek clays	40–55
1.	Blue-black papyraceous shales with selenite crystals, not distinguishable from the Kiowa, and grading insensibly into No. 2	15–15

Section IV.

On the second butte north of the mouth of Chatman creek 12 miles northwest of Ashland, Clark county, Kansas.

No.		Feet.
6.	Thin blanket of Tertiary on top of hill	2–277
5.	Black and brown sandstone often concretionary, weathering into round boulders	5–275
4.	Yellowish gray sandstone and arenaceous shales usually quite soft, distinctly stratified, containing fossil leaves and twigs, probably conifers	10–270
3.	Dark brown sandstone, often cross-bedded, and more or less conglomeratic, containing numerous white clay or limestone pebbles. Numerous fragments of fossil wood are imbedded in the sandstone. About two hundred yards north are fragments of what appears to have been a silicified log	15–260
2.	Kiowa shales with typical fossils	145–245
1.	Red Beds from the level of the mouth of Chatman creek*	100–100

Section V.

On Chatman creek where the road from Ashland to Day's ranch crosses, 12 miles northwest of Ashland and 2 miles northeast of Section IV.

No.		Feet.
6.	Tertiary to top of hill	20–112
5.	Dark brown or almost black, hard, fine-grained sandstone, mostly weathered out in blocks, containing a typical Dakota flora. The Dakota sandstone	25–92

*Thickness of Nos. 1 and 2 from Prosser's section at Butte ½ mile south. Loc. cit., pp. 166–167.

No.		Feet.
4.	Light brown to black sandstone, usually massive with pebbles and large concretions; sometimes cross-bedded and containing clay-ironstone. The Reeder sandstone	15–67
3.	Massive sandstone, yellowish to dark brown with occasional small concretions of clay-ironstone. It is usually distinctly stratified, but sometimes cross-bedded. The Greenleaf sandstone	25–52
2.	Yellowish to blue clay shale with characteristic clay-ironstone fragments covering the slopes. The Spring Creek clays	12–27
1.	Kiowa shales grading into next above	15–15

A study of these sections, together with the already well-known Comanche series, has led to the following classification of the Cretaceous rocks of Southwest Kansas:

III. Dakota Group.
  7. Dakota leaf-bearing sandstone.

II. Medicine Beds.
  6. Reeder sandstone.
  5. Kirby clays.
  4. Greenleaf sandstone.
  3. Spring Creek clays.

I. Comanche Series.
  2. Kiowa shales.
  1. Cheyenne sandstone.

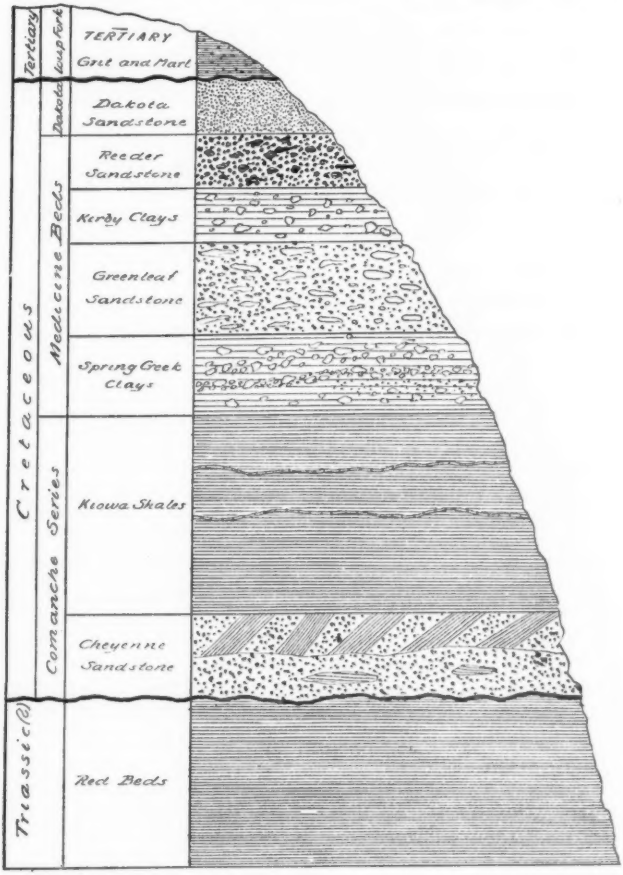
A section of the rocks of the region would be represented as shown in the accompanying figure (p. 174).

The terms Cheyenne sandstone and Kiowa shales are understood in the sense as used by Prosser.* The Spring Creek clays are named for Spring creek, a southern tributary to the Medicine river 12 miles west of Belvidere, on which the clays are well exposed. The Greenleaf sandstone is named from the Greenleaf ranch on which the sandstone was first studied, and the Kirby clays from the Kirby (also known as the C. W. or Fullington) ranch on which the clays have a typical exposure. Professor Cragin's term, Reeder sandstone, is used to include all the sandstone between the Kirby clays and the true leaf-bearing Dakota. The entire series of transition beds is included under the term Medicine beds, named from the river near the head of which the beds are best studied. The term Dakota sandstone refers to the true leaf-bearing sandstone.

The typical exposure of the Medicine beds is on Spring creek, at which point Section III was made, this being the

* Loc. cit., pp. 112–114.

only locality found where post-Cretaceous erosion has not carried away more or less of the series. Even in this locality, near the mouth of the creek the Reeder, Kirby and all but 15 feet of the Greenleaf are wanting. At this point may be seen a good example of the unconformity of the Greenleaf and Ter-



tiary, the latter containing in its lower part small, lenticular masses of the eroded Greenleaf. At Section I nothing but the Spring Creek remains and at Section II the upper part of the Greenleaf is gone.

As would naturally be expected in a series of deposits varying from deep sea to fresh water, representing several elevations and depressions, and occupying a period of apparently

rapid sedimentation, the lithology changes rapidly. Shale beds change to sandstone sometimes in a few rods. Evenly stratified sandstone suddenly becomes distinctly cross-bedded. Masses of nodular concretions, or soft, spongy, clay masses appear and disappear with no apparent regularity.

The only distinguishing characteristic of the entire series is the great number of clay-ironstone concretions which are found from the lower Spring Creek to the upper Reeder. These concretions are of all sizes and shapes; round, oblong or angular, often nearly cubical. On exposure to the air they usually break with a conchoidal fracture, exposing cutting edges, and form fragments sometimes box- or cup-shaped covering the slopes and often rendering them conspicuously brown for miles.

Dr. Lester F. Ward first found the fossil leaves on Chatman Creek. An hour's search among the broken fragments of rock lying on the surface revealed over 100 specimens. Dr. Ward identified the leaves and under the date December 6th, 1897, kindly wrote me, in part, as follows:

"The most common species is *Proteoides daphnogenoides* Heer, an original Dakota group species, described by Heer in the earliest paper on the plants of that formation, his Phyllites crétacées du Nebraska, 1866, and since found to be a very common species, but our forms are rather smaller than the average.

"We also seem to have *Embothrites daphneoides* Lx.; then there are a number of leaves that I refer to Eucalyptus. I think *E. Geinitzi*, Heer, is among them, and there is certainly one new species.* It is just possible that we also have *Laurus Plutonia*, Heer."

It may be of interest to observe that the Chatman creek locality where these leaves were found is not more than a mile from the place on upper West Bear creek from which Cragin reports "meager fragments of dicotyledonous leaves."

The "discovery of the true base of the Dakota group"† cannot but be of interest to geologists. It is to be hoped that the subject may soon be worked out in greater detail.

The writer would here make grateful acknowledgment to Dr. Lester F. Ward not only for assistance and encouragement in the field, but also for interest taken in the identification of fossils and correction of this manuscript, and to Mr. Jesse Greenleaf of Greensburg, Kansas, who kindly conducted Dr. Ward and myself to the typical localities.

Southwest Kansas College,
Winfield, Kansas, December 27th, 1897.

* Since writing this article Dr. Ward has named this species *Eucalyptus Gouldii*. See Bulletin of the Torrey Botanical Club, vol. xxiv, December, 1897, pp. 576–577.

† Lester F. Ward, Science, N. S., vol. vi, Nov. 26, 1897, p. 815.

ART. XXIV.—*Examination of some Triclinic Minerals by means of Etching Figures;* by T. L. WALKER, Geological Survey of India.

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WHEN crystals are acted upon by corroding reagents the crystal surfaces are seldom dissolved at a uniform rate. Frequently they become pitted with small corrosion or etching figures which are bounded by plane surfaces and which indicate the symmetry of the crystal surface upon which they occur. If a holohedral hexagonal crystal bounded by the prism $(10\bar{1}0)$ and the basal pinacoid (0001) be etched, then there should be two kinds of etching figures. As the basal plane has six lines of symmetry, the corrosion figures on it must exhibit six lines of symmetry which must coincide with those of the basal plane. Hexagonal figures whose sides are parallel to the edges $(0001) \wedge (10\bar{1}0)$ would satisfy the requirements of symmetry (fig. 1, p. 184). The figures on the prismatic faces must be different from those on the basal plane. Since each prismatic face is symmetrical in two directions, the corrosion pits must also conform to these requirements and must have two lines of symmetry which must be identical in direction with the symmetry lines of the prismatic face on which they occur (fig. 2). If these conditions are not fulfilled, then we are compelled to conclude that the crystal in question is not physically and geometrically holohedral hexagonal but only apparently such.

As an illustration of this use of etching figures in crystallographic studies we may refer to the case of muscovite, which was supposed to be rhombic until Baumhauer* discovered that the figures produced on (001) by treating with fused caustic potash, did not show rhombic symmetry. As there appeared to be only one plane of symmetry in the figures while a rhombic basal pinacoid should possess two lines of symmetry, it was concluded that muscovite is only pseudo-rhombic but really monoclinic (fig. 3).

By employing this method the conclusions arrived at by purely geometrical studies have frequently been corrected.

Since etching figures reveal the crystal symmetry, faces which are crystallographically equivalent, such as the eight faces of a holohedral octahedron, the four prismatic faces of tetragonal, rhombic and monoclinic holohedral forms or the two basal planes of holohedral hexagonal crystals, must give similar figures. Parallel faces are generally equivalent but not always. In the case of parallel faces at opposite ends of

* Sitzber. Akad. München, 1874, p. 245, and 1879, p. 99.

a hemimorphic axis there can be no equivalence—the basal planes 0001 and $000\bar{1}$ in the hemimorphic tourmaline being crystallographically different ought to give different etching figures. This mineral is a representative of a large class of substances whose crystals have no crystallographic center and whose parallel planes are equivalent only when this is required by other elements of symmetry—lines or planes. Thus in the case of calamine, or hemimorphite, which is devoid of a center of symmetry, we should expect the basal planes 001 and $00\bar{1}$ to give different corrosion pits, but pairs of parallel prismatic faces should give similar etching figures. This is required by the presence of two planes of symmetry (100) and (010) and may be proved as follows: the prismatic faces $1\bar{1}0$ and 110 are symmetrical about the symmetry plane (010), therefore these faces are equivalent and the etching figures on them must also be similar; but the faces 110 and $\bar{1}10$ are symmetrical with regard to the symmetry plane (100), therefore the faces are equivalent and the etching figures must be similar. But since the faces $\bar{1}10$ and $1\bar{1}0$ are both equivalent to the face 110, therefore they are equivalent to one another and will give similar etching figures, though the crystal possesses no centre of symmetry. In the same way it may be shown that all four prismatic faces are equivalent.

Very few experiments have been made with etching figures to determine the equivalence of pairs of parallel faces. I first made a few experiments to prove that parallel faces give similar figures when they belong to the same crystal form and different figures when they belong to different crystal forms, and then proceeded to examine some of the triclinic minerals with a view to determine which of them have equivalent parallel faces and which different. There are two recognized divisions in the triclinic system: first, crystals having surfaces in pairs which are crystallographically equivalent and give similar etching figures, and second, crystals whose surfaces are not always present in parallel pairs, and when they are, do not give similar corrosion figures and are not crystallographically equivalent. The first group are holohedral triclinic, and since they possess a centre of symmetry, Zirkel and others refer to them as *centro-symmetric*. The second group is often referred to as hemihedral triclinic or tetartohedral monoclinic, but as the crystals possess no element of symmetry, whether of line, plane or point, they are appropriately spoken of as *asymmetric*. Up to the present time no mineral representative of this latter group is known. A small number of complete artificial chemical salts crystallize in asymmetric forms.

Etching Figures on Tourmaline.—I selected a transparent greenish yellow crystal of tourmaline about a quarter of an inch in diameter. The prismatic zone was composed of the trigonal prism $\frac{\infty R}{2}$ $(10\bar{1}0)$ and the prism of the second order $(11\bar{2}0)$. One end was terminated by a single plane, the basis 0001, while the other end was not crystallographically terminated, a part of the crystal being broken off. The crystal was sent to R. Fuess of Berlin with the request to prepare two thin polished plates parallel to the base. After several fruitless attempts, I finally succeeded in obtaining good etching figures, by bringing the already slightly warmed tourmaline plate into a red-hot mixture of potassium bisulphate and coarsely powdered fluor spar. Below red heat no corrosion took place. After ten minutes the crystal was withdrawn from the red-hot fusion and allowed to cool slowly so as to prevent cracking. By treating with hot dilute hydrochloric acid it was easily cleansed from the coating of the corroding mixture. On examination with the microscope the face corresponding to the natural basis, 0001, was seen to be well covered with small figures which may be described as sharply angular equilateral triangles, with their sides parallel to the edges of the trigonal prism and basal plane and the angles pointing toward the above mentioned edge (fig. 4). The figures on the parallel face—the artificial basis $000\bar{1}$—are also equilateral triangles, but the sides are curved and the angles blunt. A closer examination showed that the little figures are probably nine-sided and closely resemble sections through many tourmaline crystals whose prismatic zone is composed of the forms $(10\bar{1}0)$ and $(11\bar{2}0)$, the former predominating so as to give a trigonal habit to the crystal, with the latter forming narrow faces bevelling the edges of the trigonal prism. The chief sides of the corrosion figures are parallel to the edges of the trigonal prism and the base, but the angles of the triangle are turned away from the edge of the trigonal prism. This is shown in a more or less idealized form in fig. 5. Thinking this difference between sharp and blunt triangles might be due to the position or temperature of the crystal during the reaction, I etched the second polished plate, taking the precaution to hold it in such a position, by means of platinum pointed forceps, that both should be subject to exactly the same conditions. The resulting figures were quite like those on the first plate. The high temperature caused the greenish yellow crystal plates to become water-clear.

These figures are different, but as the basal planes of tourmaline contain three lines of symmetry the figures on *both* planes must also contain three lines of symmetry and these

must coincide with the lines of symmetry of the basal planes. A glance at figures 4 and 5 will show that this is the case. Although the trigonal axis of symmetry of tourmaline compels the figures to be built on the plan of the equilateral triangle, yet while conforming to this requirement the difference in the faces 0001 and 000$\bar{1}$ is very clearly indicated by the difference of the etching figures.

Acid Dextro-Tartrate of Strontium.—This is one of the best known and most easily prepared of all the substances crystallizing in the asymmetric or hemihedral division of the triclinic system. Dr. Steeg & Co. of Homburg v. d. Höhe supplied me with a few very fine crystals for examination. These crystals possess one very perfect cleavage direction, which, according to the orientation proposed by A. Scacchi* and adopted by Liebisch,† is taken to be the basal pinacoid (001) and (00$\bar{1}$). Very thin cleavage plates are easily prepared which serve very well for etching. As the substance is readily soluble in water, good figures were prepared by placing the cleavage fragment between folds of a piece of *very* slightly moistened calico and pressing between the finger and thumb for twenty seconds. A microscopic examination showed that the figures on 001 were four-sided with their sides parallel to the edges of the cleavage plate. The four sides of the corrosion pits are nearly equal (fig. 6). On the parallel face 00$\bar{1}$ the figures are also four-sided but very slender, almost reduced to mere lines at times (fig. 7). After etching and examining a large number of cleavage plates, I satisfied myself that these figures are unmistakably different and eminently characteristic for the two faces upon which they occur. It would be impossible to confuse them. So much is this so, that if a crystal were split into half a dozen cleavage plates and these etched, then by means of the difference of the figures the upper and lower surfaces could be distinguished and the crystal reconstructed with all the fragments properly oriented.

So far as I know, the only previous experiments made with etching figures with a view to determining the crystallographic equivalence of pairs of parallel faces, are those made by Miers on spangolite. This hemimorphic hexagonal mineral had been described by Penfield from a single specimen from Arizona, when Miers found it on some specimens of Cornish copper minerals. In his description in the Mineralogical Magazine he says: "In order to obtain independent evidence of the hemimorphic character of this mineral, experiments were next made upon etched figures, it being thought that possibly some

* A. Scacchi, Atti. Accad. delle Sc. Fis. e Mat., Napoli, 1, 1863.
† Grundriss der Krystallographie, p. 176, Leipzig, 1896.

difference might be found between the etching upon the upper and under surface of a cleavage plate. This was found to be the case; cleavage plates exposed to the action of dilute hydrochloric acid showed upon both sides the characteristic etched triangles figured by Penfield. These were identical in form, but very different in dimensions; the plates were invariably attacked with much greater rapidity upon the lower or attached end than upon the surface directed toward the unattached end of the crystal."*

I was not aware of Miers' experiments till after those on tourmaline and acid dextro-tartrate of strontium were completed and this paper written in almost its present form.

From the experiments above described I think the desired confirmation has been given to the statement:—*Crystal faces belonging to the same crystal form give identical or similar etching figures, while faces belonging to different crystal forms give different etching figures even if the faces be parallel to each other; or conversely, if parallel faces give different etching figures, the faces do not belong to the same crystal form.*

Taking the above statement as a basis, I proceeded to examine some of the common triclinic minerals with a view to determining which of them are centrosymmetric and which asymmetric.

Axinite.—I was fortunate enough to obtain a few of the beautiful crystals from Bourg d'Oisans in Dauphiné. This mineral has been crystallographically described by many authors, so that several different ways of orienting the crystals are in common use. The references in this note are to Naumann's orientation, which is probably the one most generally used by English and American mineralogists.

By acting upon the crystals for five minutes with a hot mixture of equal volumes of concentrated sulphuric and hydrofluoric acids, very sharp figures were obtained. The most easily examined and at the same time most striking are those on $1\bar{1}1$, which is the face designated by the letter *r* by Naumann and Schrauf. The figures contain no line of symmetry. Those on $1\bar{1}1$ and $\bar{1}1\bar{1}$ are illustrated in figures 8 and 9 and are related to one another in the same way as the right hand is to the left. This, however, is in accord with crystallographic characteristics of the system, the faces being related to each other in the same way, so far as outline is concerned. This dissimilarity is well seen in the case of the pyramidal faces in the rhombic system. The eight faces of a simple rhombic unit pyramid are all scalene triangles; the triangular faces 111,

* Min. Magazine, vol. x, p. 276, 1894.

$\bar{1}\bar{1}1$, $1\bar{1}\bar{1}$ and $\bar{1}1\bar{1}$ are equal to one another and are identical in form—these triangles can be placed upon one another so as to coincide *without being turned over*. The faces $1\bar{1}1$, $11\bar{1}$, $\bar{1}\bar{1}\bar{1}$ and $\bar{1}11$ bear to each the same relationship and may be made to coincide by superposition *without being turned over*. The triangles of the first group cannot be made to coincide except by turning over. The triangles of these two distinct groups are related to one another as right and left. Suppose that on such faces we have etching figures, triangular in outline and with their edges parallel to those of the triangular face upon which they occur. They too must be related to one another as right and left, but with this difference, that the corrosion pits have three dimensions, and by turning over the triangular outlines may coincide, but the pits will then project in opposite directions and will form a closed space which will be symmetrical about the plane of contact. This is quite like the relation that the valves of a clam shell bear to one another—they can never be so turned as to fit into one another. So also the cast of a corrosion pit on a pyramid face of one of the above groups cannot be fitted into a pit on a face of the other group. The one is the mirror image of the other turned about 180°. The figures accompanying this paper have generally been turned in this way so that the image relationship may be plainly seen.

For clearness it would be well to refer to figures which agree in all respects as identical—those on all the faces of either of the above groups are *identical;* figures which have the right and left relationship may be referred to as *similar*, while all corrosion pits not belonging to either of these classes may be designated as *different*.

The dagger-shaped figures on the faces $1\bar{1}1$ and $\bar{1}1\bar{1}$ of axinite crystals being *similar*, we must conclude that the mineral is centro-symmetric.

Cyanite.—Pale blue crystals from St. Gothard were used. They are well developed in the zone of the vertical axis showing the forms (100) (010) and (110). The crystals are contained in paragonite schist and are elongated in the direction of the vertical axis. As the mineral is very cleavable along (100), good material is easily obtained for etching. Their cleavage fragments, which had been previously carefully warmed, to avoid decrepitation or unnecessary shattering from suddenly heating, were plunged into a red-hot mixture of potassium bisulphate and coarsely powdered fluorspar. After one or two minutes they were taken out, allowed to cool slowly and then cleansed by boiling with hydrochloric acid. Very satisfactory figures were obtained. Those on 100 are shown in fig. 10

and are similar to those on $\bar{1}00$ (fig. 11), thus indicating that the mineral is centro-symmetric triclinic.

Chalcanthite, or Copper Vitriol.—This triclinic mineral rarely occurs in well developed crystals, so that the crystals etched were artificial and grown from a saturated solution of copper sulphate. About twenty grams of ordinary "blue stone" was dissolved in hot water to concentration, acidified with a few drops of sulphuric acid, filtered and allowed to cool, when the larger portion crystallized out. The solution was poured into a second dish and after twenty-four hours half a dozen well-formed crystals had separated. These were used for examination. The corrosion figures were obtained by increasing the temperature of the saturated solution, from which the crystals had grown, about two degrees. When the warm (comparatively) mother liquor had reacted for sixty seconds the crystals were removed and quickly dried with filter paper. The figures resulting in fig. 12 are those formed on the front face of the left hemiprism $1\bar{1}0$. Those on the parallel face $\bar{1}10$ are seen in fig. 13. As the corrosion figures on the parallel faces are similar, we conclude that chalcanthite is centro-symmetric triclinic.

Rhodonite.—Fragments of rose-colored crystals from Långbangshytta, Wermland, Sweden, were treated for one minute with a warm mixture of equal volumes of concentrated sulphuric and hydrofluoric acids. As this mineral is very rich in crystal forms and exhibits many different types, accordingly having only fragmentary crystals to work upon, it was difficult to determine with certainty the symbols for the faces. The corrosion figures from two parallel faces are represented in figs. 14 and 15. The faces in question were largely developed, striated and were cut obliquely by the two principal cleavages, presumably (110) and $(1\bar{1}0)$. Though not certain, I have assigned the figures to the basal pinacoids 001 and $00\bar{1}$ according to Dana's crystallographic orientation of the mineral. The striation referred to is parallel to the longer direction of the etching figures. The corrosion pits are such as to warrant the conclusion that the mineral is centro-symmetric triclinic.

Albite.—The material employed for this examination consisted in two or three small water-clear crystals from the Alps. Cleavage fragments parallel to (001) were easily prepared, on which the angle of optical extinction was measured under the microscope and found to be $+4° 54'$, thus proving the crystals to be a plagioclase free from lime, that is albite. By treating

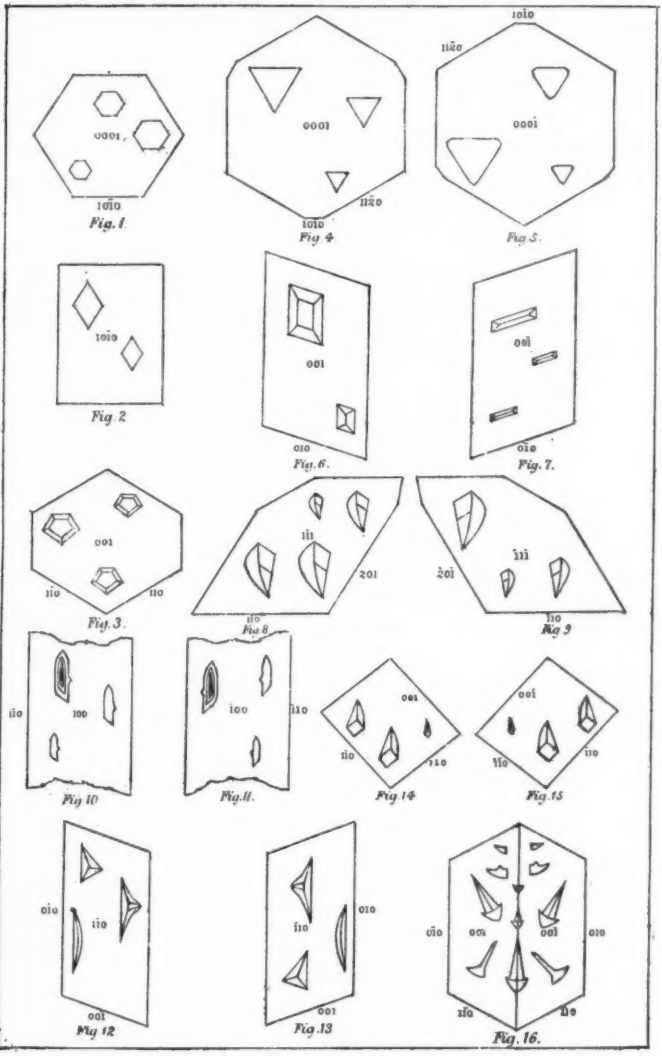
for thirty seconds with a half-and-half mixture of sulphuric and hydrofluoric acids, very interesting figures were obtained. At first sight there seems to be no regularity about them, but it is soon seen that all the figures can be referred to a very simple primitive corrosion pit which resembles in outline a right-angled triangle whose sides are 3, 4 and 5, the shortest side being parallel to the brachypinacoidal edge and the smallest angle directed towards the left. The figure on $00\bar{1}$ is similar and has its smallest angle pointing in the opposite direction. Figure 16 represents a basal cleavage fragment from an albite crystal simply twinned according to the albite law. On the left are the figures on 001 and on the right those on $00\bar{1}$. The primitive figures are seen to give, on further development, such pits as those shown immediately below them. The arrow-headed corrosion figures are the commonest and appear to be the adult or final form. All intermediate stages in development between these are plainly seen under the microscope. The offshoot from the primitive form may take place from one of the angles and produce nail-shaped figures. This can take place from any of the three angles and can be traced through all the intermediate stages. It is commonest from the right angle of the triangle, as is the case in the instance figured.

Since the primitive form gives rise to four different final forms or types and a large number of intermediate stages, it is not surprising that at first sight one should not see any definite order. The first, third and fourth types are the commonest.

This development from simplicity and uniformity to variety and complexity appears to be almost as common in crystal life as biologists have shown it to be for organic life. Minute crystals and tiny etching figures give promise of a heterogeneity and variety which they do not actually possess in their earlier stages of development.

But there is another form of etching figure to be noted. Suppose a figure should begin exactly on the line of contact between twinning lamellæ, the figures would develop symmetrically on both sides of the line of contact. This is illustrated in figure 16. These figures possess a plane of symmetry and are such as we might expect on the basal plane of a monoclinic crystal. If the albite twinning lamellæ were very, very thin, then all the figures would be like these, because every figure would be large enough to extend across several lamellæ. This only proves by means of etching figures what has been long known from geometrical crystallographic studies —viz, that twinning increases the symmetry of a crystal.

Some of the pits above described are represented in the



See next page for Explanation of Plate.

drawings as if some of their surfaces were curved. This only means that there are a large number of faces present, so that the figures *appear* to have curved surfaces, just as prisms of tourmaline often appear to be rounded. There does not seem to be any reason to depart from the opinion of Baumhauer and Becke, who hold that the surfaces of etching figures are never curved but always plane.

The small number of minerals dealt with in this paper were selected generally because they were most easily obtained in suitable specimens, at other times because they gave definite results. I hope to describe more of the triclinic minerals at a future time.

My thanks are due to Babu Nrependra Nath Bose, who has redrawn the figures from sketches made by myself.

Indian Museum, Calcutta, Nov. 1st, 1897.

EXPLANATIONS OF PLATE.

FIGURE 1.—Corrosion figures such as might be formed on the basal plane of a holohedral hexagonal crystal.

FIGURE 2.—Corrosion figures showing the symmetry of the prismatic face of a holohedral hexagonal crystal.

FIGURE 3.—Figures on basal plane of muscovite showing monoclinic symmetry—produced by fused KOH.

FIGURES 4 and 5.—Figures on 0001 and $000\bar{1}$ of tourmaline showing the physical difference between the two parallel planes—produced by red hot fusion of $KHSO_4$ and CaF_2—time 2 minutes.

FIGURES 6 and 7.—Figures on 001 and $00\bar{1}$ of acid dextro-tartrate of strontium. Produced by pressing between very slightly moistened folds of calico for 20 seconds.

FIGURES 8 and 9.—Figures on $1\bar{1}1$ and $\bar{1}1\bar{1}$ of axinite—produced by a hot mixture of equal volumes of strong H_2SO_4 and HF acting for 5 minutes.

FIGURES 10 and 11.—Cyanite, 100 and $\bar{1}00$—$KHSO_4$ and CaF_2 at red heat for 1 to 2 minutes.

FIGURES 12 and 13.—Copper vitriol, $1\bar{1}0$ and $\bar{1}10$. Produced by raising the temperature of the mother liquor in which the crystals had grown 2°C. and allowing the slightly warmed solution to corrode for sixty seconds.

FIGURES 14 and 15.—Rhodonite, 001 and $00\bar{1}$, hot mixture of equal volumes of strong H_2SO_4 and HF—time 60 seconds.

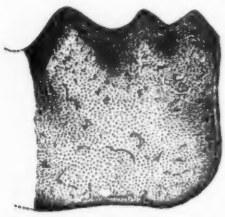
FIGURE 16.—Albite simply twinned—shows figures on 001 and $00\bar{1}$—same reagent as in 14 and 15—time 30 seconds.

Art. XXV.—*Some new Jurassic Vertebrates from Wyoming.* First Paper; by Wilbur C. Knight.

For the last three years the University of Wyoming has had parties in the field collecting vertebrate remains from the Jurassic rocks. Much of the material collected is new to science and will be described as soon as it is possible to study it properly. Among the lower forms are two new species of Ceratodus, a genus not well represented in the American terranes.

Ceratodus robustus, sp. nov. (Fig. 1.)

1.



Ceratodus robustus, natural size.

The description of this species is based upon the greater portion of a supposed right mandibular tooth, the anterior margin and first horn having been broken off. The known portion of the tooth is quadrangular in form. The anterior and posterior margins are nearly straight and are at right angles to each other. Posterior inner corner of tooth rounded. Exterior margin divided into four short, broad rounded horns, separated by three broad, shallow, rounded depressions. Surface of the tooth very large, and not cut by the angular depressions as in most of the Ceratodi. The tooth is fastened to a piece of the dentary bone that measures 33^{mm} long, 31^{mm} wide and 10^{mm} thick. The fragmentary tooth measures 29^{mm} long, 31^{mm} wide and 10^{mm} thick. So far as known there are no closely allied forms. This species was discovered by the writer in Albany county, and was associated with the bones of a crocodile and a supposed new Dinosaur.

Ceratodus americanus, sp. nov. (Fig. 2.)

2.

Ceratodus americanus, natural size.

All that is known of this species is a left mandibular tooth.* It is triangular in shape. The interior and posterior margins merge into one, and form a well-rounded outline. Anterior margin nearly straight. The junction of the anterior and interior margins truncated. The exterior margin is divided into four angular horns, separated by three angular depressions. The first and largest horn is separated from the second by a right angular depression. The greatest length of the tooth is 21^{mm}, greatest width 17^{mm}. This species is probably closely related to *C. guntheri*† Marsh. It was found by the writer in Carbon county, and was associated with the bones of a Megalosaur.

University of Wyoming, Laramie, Nov. 30th, 1897.

* I am not absolutely certain that this is a mandibular tooth. It is possible that one horn has been broken off, in which case it would belong to the right palate.

† This Journal, III, vol. xv, page 76.

ART. XXVI.—*On the Accessory Elements of Itacolumite, and the Secondary Enlargement of Tourmaline;* by ORVILLE A. DERBY.

THE peculiar type of granular quartz-rock characteristic of the gold and diamond regions of the Serra do Espinhaço in the state of Minas Geraes, Brazil, which has come to be generally known by the name of itacolumite, proposed in 1822 by Eschwege,* has given rise to much discussion. Eschwege and the majority of subsequent writers on the geology of the region (Helmreichen, Claussen, Pissis, Heusser and Claraz) regarded it as a member of the primitive group of rocks having a special mode of formation, an idea that has found expression in some recent text-books of geology (Lapparent, Traité de Geologie, 2d ed., Paris, 1885). Later writers (Hartt, Liais, Gorceix, Derby) have regarded it as a metamorphosed sandstone. The view that it is only a special phase of an ordinary sandstone has also been presented, though not, so far as known, by any geologist who has seen it in place. The most definite evidence thus far presented by the advocates of any one of these discordant views is that of the very pronounced and characteristic schistose structure by those who maintain the metamorphic hypothesis, but the force of this argument, which was long considered as conclusive in favor of a clastic origin, has been greatly weakened by recent studies on the crystalline schists.

On the hypothesis that, if clastic as presumed, some internal evidence of the mode of origin might be found in the mineral elements of the rocks themselves, a microscopic examination has recently been made of the isolated grains separated by washing from hand specimens of the rock, from several of the typical localities in Minas Geraes as well as from other points in the same state and from those of Goyaz and Bahia. As the original itacolumite of Eschwege was divided by him into a schistose and massive group, which, by later writers (Derby, Gorceix), have been considered to be independent formations, it may be stated that the material examined was for the most part known, or presumed, to represent the schistose and older group, and that in several instances the specimens presented the property of flexibility which was for a long time, but erroneously, supposed to be characteristic of the rock as a whole.

The quartz grains of these rocks present no unequivocal

* Geognostiches Gemälde von Brasilien, und wahrscheinliches Muttergestein der Diamanten, Weimar, 1822.

evidence of clastic origin. They are sharp and angular with jagged outlines and perfectly fresh surfaces, as in the crystalline schists generally and in many eruptive rocks as well. The clearest indication of a clastic nature, that of a difference in the size of the grains in some specimens, is of doubtful value, since metamorphosed eruptives of original porphyritic structure might present it as well. No cases of the secondary enlargement of worn grains such as have been described by Törnebohm, Irving and others, could be detected in typical samples of the rock, as those showing such enlargements present macroscopically the aspect of sandstone rather than of itacolumite. These are from the diamond district of Lençoes in the state of Bahia, where both types of rock occur (the itacolumite very abundantly as rolled pebbles in the sandstone or conglomerate), and one of the specimens is highly charged with tourmaline in a manner suggestive of contact metamorphism.

The mica (or mica-like) mineral which is almost invariably present in greater or less abundance is also perfectly fresh and is undoubtedly authogenic. Formerly referred to talc or chlorite, it proves in most places to belong to some of the varieties of muscovite. The predominant type is white with a pearly luster, but a green variety suggestive of fuchsite is quite common. That of a specimen representing the diamond-bearing bed of Grão Mogol (massive itacolumite of Eschwege and Helmreichen) is a green brittle mica of high specific gravity and apparently a member of the clintonite group. A specimen of sandstone with a small stringer of vein quartz from the Lençoes region in Bahia shows green mica in the vein and in the microscopic fissures of the rock for a centimeter or so in its immediate vicinity, but not in the general mass of the rock, which is a typical clastic sandstone. From this case it appears that the production of mica in these rocks does not necessarily indicate an advanced degree of metamorphism.

Among the rarer accessories zircon is the most constant and the only one that, in most cases, presents unequivocal evidence of an allothogenic origin in the rounded angles and dulled luster of the faces due to wear in transportation. (As the angles of zircon are often rounded in eruptive rocks in which it is undoubtedly an authogenic element, this character alone cannot be taken as an evidence of wear.) In a few cases the mineral is rare and extremely minute and in these the signs of wear are indistinct. In the most of the specimens examined, however, the zircons are more abundant than would be expected in a corresponding volume of a zirconiferous eruptive, showing an apparent concentration which of itself is an indication, though not an unequivocal one, of clastic origin. When of

fair size and abundant, the signs of wear are generally so distinct as to be unmistakable. The predominant type is that of short, stout, rounded prisms, frequently of a rose color and sometimes partially whitened (by incipient malaconization in the parent rock?), which is suggestive of granite or granitic gneiss as the original rock from which they were derived.

The iron ores, magnetite and hematite are usually present, though often in very minute quantities. The two oxides sometimes occur together, though in general hematite is the most abundant and characteristic. Both are sharp-angled with lustrous faces and are evidently authogenic. Pyrite is frequently present and often in octahedral forms which on becoming altered to limonite (or hematite?) afford martite-like forms difficultly distinguishable from those derived from magnetite. Ilmenite has not been observed, though titanium oxide in the form of isolated crystals or aggregates of rutile or anatase, or both, is frequent and always with the perfectly fresh appearance of an authogenic element. Considering these rocks, on the evidence of the zircons, as original sandstones derived from granites or gneisses and with a certain concentration of the heavy accessories of the parent rock, the presumption is that the iron ores would be equally or more abundant than the zircons and be represented by magnetite, titaniferous magnetite or ilmenite. On this hypothesis, there has been in the metamorphism of the rock a notable reduction in the quantity of the free iron oxides, a recrystallization of the remaining portion as hematite and more rarely as magnetite, and an isolation of the titanium oxide when present as rutile or anatase. The iron oxide that has disappeared as such has perhaps gone to the green mica, or the pyrite, or possibly has been leached out. In connection with the supposed isolation of the titanium from ilmenite, an iron sand from the diamond region of Lençoes in Bahia is interesting. Agglomerated nodules of worn, or etched, grains of iron oxide giving the characteristic streak of hematite show perfectly fresh microscopic rutile in the interspaces between the grains. They are presumed to come from the sandstone formation of the region and to represent an ancient natural concentrate of black sand (magnetite, perhaps titaniferous, and ilmenite) in the original sediments. As is well known, the transformation of magnetite to hematite and the formation of rutile and anatase from titanium-bearing minerals (sphene or ilmenite) may take place in the process of atmospheric weathering, and are not therefore necessarily indicative of metamorphism. When, however, as in the case of the rocks in question, the hematite takes the form of a well-crystallized specular iron, it may be presumed that true metamorphic changes are involved.

A frequent, though not constant, accessory is tourmaline in minute prisms, or prismatic fragments, with lustrous faces. The appearance of the grains is that of an authogenic element even when, as in two cases, there is evidence of a new formation about allothogenic grains. These two cases are in the residue from the rocks of the Jurumerim cutting on the Minas e Rio Railroad in southern Minas Geraes, where the observations on the flexibility of itacolumite recorded in this Journal (vol. xxviii, 1884, p. 103) were made, and from a decomposed rock of a cutting on the Mogyana Railroad close to the station of Rifaina, near the Rio Grande bridge on the boundary between São Paulo and Minas Geraes. In these residues a considerable number of the larger grains of tourmaline show a dark, sometimes completely opaque, nucleal portion enclosed in lighter colored transparent material having the same optical orientation. At first sight the appearance might be taken for zonal structure, but with proper illumination, the dark nucleus is seen to be either well rounded with a fretted surface indicative of wear, or angular with outlines that do not correspond with those of the completed individual, as would be the case with zonal structure. The accompanying figures, kindly drawn by Dr. E. Hussak, show some of the most interesting cases observed. Figs. 1 to 5 are from Jurumerim, fig. 6

from Rifaina. Basal sections (1 and 2) are nonpleochroitic. In sections parallel to the *c*-axis the nucleus is black when this axis is perpendicular to that of the polarizer, and dark brownish red when parallel to it, though it is often necessary to concentrate a very strong light on the dark center for it to appear translucent. The rounded nuclei represented by figs. 1, 2, 3 and 6, show a roughened surface indicative of wear which is less distinct, or imperceptible, in the angular fragments like fig. 4. In one case the light-colored tourmaline substance of the outer shell was seen filling a deep V-shaped embayment in the rounded surface of the dark nucleus. The lower dark grain in fig. 5 is an iron ore, probably magnetite.

The whole appearance of these dark-centered tourmalines is that of clastic grains, either well rolled or recently broken, that have been enlarged by a new formation of the same substance which, as in the well-known case of enlarged quartz grains, takes on the same optical orientation as in the fragment that serves as a nucleus. The amount of tourmaline in the

rocks in which the phenomenon has been noted is not so great that the newly-formed additions, and the grains that do not exhibit secondary enlargements, may not reasonably be attributed to a readjustment of material already existing in the rock as clastic elements, rather than to the introduction of new material. On this hypothesis the frequent and wide-spread occurrence of minute quantities of tourmaline in rocks where its presence cannot be attributed to contact metamorphism, may perhaps be satisfactorily explained. The secondary enlargement of tourmaline seems to have been already observed in similar rocks (see Van Hise, 16th Ann. Rpt. Geol. Sur., p. 685), but I have been unable to find any account of it.

Considering the itacolumites as original sandy sediments derived for the most part from granites and granitic gneisses, other frequent accessories of these latter rocks, and more especially the phosphates, monazite, xenotime and apatite, might be expected to occur, at least sporadically, in them. A careful search failed to reveal unequivocal evidence of their presence, though dubious grains were noted that are suggestive of worn and partially corroded monazite and xenotime. The hypothesis that they may have disappeared, giving rise to new combinations, is favored by the somewhat frequent occurrence of the aluminium phosphate, lazulite, in these rocks, and of amorphous phosphatic masses (*favas* of the diamond miners) in the detritus derived from them or their associates. To test this hypothesis, a small fragment of itacolumite containing lazulite, evidently authogenic, was examined in the hope that some trace of an original clastic phosphate might still be found. In fact, along with some dubious grains suggestive of altered and corroded xenotime, an undoubted intergrowth of this mineral was detected. There is therefore direct evidence of the association of newly-formed and clastic phosphates in the same rock, which, taken in connection with the strong antecedent probability of the occurrence of allothogenic phosphates in these rocks and their apparent disappearance, and with the fact that monazite and xenotime are frequently partially altered and corroded in the decay of eruptive rocks, gives a reasonable degree of plausibility to the hypothesis. Further observations on this point are however desirable.

The observations here recorded and others less complete on the argillaceous rocks associated with them, show that with the degree of metamorphism that this series exhibits, all of the original clastic elements except zircon are subject to changes that may obliterate or render dubious their evidence of such origin. In addition to the well-known processes of fragmentation, recrystallization and secondary enlargement by which such evidence may be obliterated, by the renovation of worn

surfaces, etching has in several cases been noted. In the cases of quartz and of staurolite in which it is most pronounced, the etching seems to have taken place during the decay of the rocks. In the few cases in which it has been rather indistinctly observed on zircons, it appears to be attributable to magnetic absorption, to which also the rounding of the angles, when found in eruptive rocks, is probably due. Whether in more completely metamorphosed rocks these changes may render zircon also useless as an evidence of clastic origin, is a question to be investigated for which material is unfortunately not at hand. The observations thus far made on siliceous and argillaceous rocks, both eruptive and clastic, give a hope that it may prove to be a reliable witness in the great majority of cases. The occurrence of macroscopic zircons in calcareous rocks, however, indicates either an introduction of new material or a migration and concentration of the material of microscopic clastic grains that occur in most limestones when not absolutely pure. An investigation of this point in some of the well-known zircon localities would be of interest.

Art. XXVII.—*Auriferous Conglomerate of the Transvaal;** by George F. Becker.

The auriferous conglomerate of the Witwatersrand gold-field, South African Republic, constitutes the most important gold deposit ever known. Without counting imperfectly explored extensions, the workable area is a strip of country a couple of miles in width and about 30 miles in length. This little district has yielded since 1887 about 240 million dollars worth of gold, and careful estimates indicate that only about one-fifteenth of the accessible gold has been extracted. The production is increasing rapidly. The output in 1897 was one-third greater than that in 1896, and reached 3,034,674 ounces, worth about $51,675,550. During 1897 the other gold fields of the Transvaal (which equals Arizona in area) produced enough to bring the total product up to $58,434,000. The total product of the United States in 1896 was in round numbers 53 million dollars, but that for 1897 is estimated at 61½ millions.† It is evident that the banket is a very notable factor in the financial policy of all commercial nations, and even in the party politics of the United States.

The nature of this wonderful deposit is a subject of manifest interest to geologists and mining engineers, who, however, have arrived at various conclusions. No considerable doubt exists that the puddingstone is a marine littoral deposit, but some observers have held that the gold is detrital, being part and parcel of the conglomerate; others that it is a chemical precipitate from the ocean in which the pebbly beds were laid down; and still others that the precious metal reached the uplifted but uncemented gravel in solution, so that the ore-bearing strata are allied to ordinary veins. Two authorities regard the deposits as in part detrital and in part venous impregnations.

The banket skirts the southerly edge of a large area dotted over with proclaimed gold-fields in which ordinary veins are associated for the most part with crystalline schists. This area

* This paper, which has been prepared at the request of the editor of this Journal, is essentially an abstract of a longer one, "The Witwatersrand Banket with notes on other Gold-Bearing Puddingstones," U. S. Geol. Survey, Ann. Rep., 1896–97, Part V. It contains, however, references to opinions by Messrs. Stelzner and Zirkel, which I had overlooked; and to a paper by Mr. John Hays Hammond which has just appeared. For permission to publish this material I am obliged to Mr. R. H. Benson.

† The South African mining companies turn in statistics of their production with admirable promptitude, but unfortunately in terms of ounces of crude bullion and in spot values. The returns of the English mint show that the average fineness is 0·8475 or $17.52 per ounce, coining value.

includes the northern part of the Transvaal and portions of Mashonaland and Matabeleland. Its extent is approximately 130,000 square miles and the remnants in it of prehistoric workings are so extensive as to lead to the belief that gold to the value of millions of pounds sterling has been extracted. The ancients, however, appear to have been unaware of the auriferous character of the banket. The age of the rocks in the northerly area is uncertain but it is supposed to be Silurian or older. They are known as the Swasi schists. They are certainly older than the banket beds, the more important of which occur in the Lower Cape formation. This, by imperfect correlation with occurrences near Cape Town, is thought Devonian or Lower Carboniferous. A less important banket, the Black Reef, occurs in the Upper Cape which rests unconformably on the lower series. The Triassic coal-bearing series is separated from that containing the Black Reef by another unconformability and shows only traces of gold.

The uplift of the Lower Cape was of moderate violence and took place under no great load. The northerly edge of the series was sharply bent upwards and the outcrops are now found at angles of southerly dip usually included between 45° and 70°. To the southward, underground, the strata rapidly flatten; so that in the lower workings dips of 20° to 30° are common. The bending of the beds was achieved to a smaller extent by plastic flexure than by multiple systematic fractures, and many of the faults are marked by dikes of subsilicic pyroxenic rocks. The main period of uplift and dike injection occurred before the Upper Cape. In such cases of what may be called *comminute flexure*, the fractures though simultaneous dislocate one another at the instant of formation. When filled with dikes or veins they often give the erroneous impression of successive disturbances. There appear, however, to have been along the Witwatersrand some relatively unimportant injections of later date than the main uplift.

Associated with the dikes, and manifestly connected with them genetically, are numerous quartz seams. These cut the country as irregularly as the dikes. As a rule they show neither gold nor sulphurets, but sometimes masses of pyrrhotite and a little pyrite are found in them, and in a few cases pockets of gold have been encountered, particularly, it is said, at their intersection with the reefs. It is possible that this last conclusion is an erroneous one, for the white veins nowhere contain gold so distributed as to form workable ore in considerable quantities, and it is only where they cross drifts or stopes that they are broken down. There is no way of ascertaining just how much gold has come from the pockets in the white quartz, but opinions among the managers seem agreed that it does not

exceed a few thousand pounds in value. With this exception all of the gold of the Witwatersrand occurs in the banket reefs, of which by no means all carry gold in remunerative quantities.

The banket is a highly siliceous mass, consisting of quartz pebbles embedded in a matrix composed of sand, pyrite, and other minerals, all cemented by secondary silica. The cement has the same character as in ordinary quartzite. The large quartz pebbles have all the characteristics of vein quartz, but show under the microscope undulous extinctions and other evidences of the dynamic action to which they have been subjected. They are frequently cracked, and then sometimes show veinlets along the fractures. The quartz pebbles often carry pyrite and other sulphurets, as zinc blende and galena. This was recognized by Dr. A. Koch,* who states that pyrite occurs as inclusions in the quartz pebbles of almost all the conglomerates. So, too, Mr. A. Pelikan† states that in the suite of specimens which he has examined pyrite is found as inclusions in the quartz pebbles. Mr. De Launay denies this occurrence. Gold and pyrite, he says, exist exclusively in the cement, never in the pebbles. In the Crown Reef mine I found more than a dozen instances of the inclusion of sulphurets in the course of a brief search, and I observed a great number of such cases in other mines on subsequent occasions. These were cases in which the sulphurets were disseminated through the quartz of the pebbles, not arranged on surfaces which might be interpreted as recemented cracks. Under the microscope I find many cases of the inclusion of disseminated pyrite in pebbles of what is plainly vein quartz. Some of the sulphuret-bearing pebbles are auriferous. One such which I collected in the Crown Reef was large enough to bear trimming, so that the outer surface could be entirely removed. The residual kernel was assayed by Mr. A. F. Crosse and found to contain gold in appreciable quantities. Prof. Le Neve Foster‡ states that assays by Mr. Richard Smith show some of the pebbles to be auriferous. The question whether free gold exists in the pebbles has been much discussed, and has been treated as if it were a matter of the first importance in deter-

* Vorkommen und Gewinnung der nutz. Min. in der Südafr. Republik, by Carl Schmeisser. 1895, p. 48.

† Verhandl. k. k. geol. Reichsanstalt, 1894, p. 421. Dr. Koch examined banket from the Simmer and Jack, Robinson, Village Main Reef, Meyer and Charlton, and Langlaagte Estate. Mr. Pelikan's specimens came from the Robinson, Crown Reef, and Meyer and Charlton. I have slides from the Ferreira, Village Main Reef, Crown Reef, Simmer and Jack, Robinson, City and Suburban, and the Crown Deep. I have also examined a series from the Ferreira owned by the general manager, Mr. Harry Johns.

‡ Text Book of Mining, 1894, p. 42.

mining the nature of the gold deposits. This is quite a mistake, as I shall explain somewhat later. I was assured that free gold has repeatedly been observed in the pebbles with the naked eye, but I did not succeed in getting a sight of any such specimen. Mr. Pelikan, however, has found moss gold embedded in the quartz of his specimens, and has photographed under the microscope the occurrence of gold embedded in quartz. These photographs are published in Mr. Goldmann's work,* with different tints for pyrite and gold. I possess a slide of Ferreira ore which shows free gold solidly embedded in a quartz pebble.

The matrix of the banket contains most of the gold and pyrite. Some of the pyrite in the matrix is said to be in well-defined, sharp crystals, but much more of it is in the form of rolled pebbles. In some of the ores of the district it is evident to the naked eye that pyrite pebbles exist, but in most cases a thin section is needed to display them. Dr. Koch says that the grains of pyrite are generally shaped by attrition, or at least display rounding of the edges and corners. This is confirmed by Mr. Pelikan. Mr. De Launay also calls especial attention to the fact that the pyrite often occurs in grains which are rolled, or at least broken, blunted, or rounded. He finds such pyrite pebbles extremely prevalent both in the Main Reef series and elsewhere. He considers the pyrite pebbles as auriferous, and mentions having observed under the microscope gold embedded in the pyrite, without stating whether in these particular instances the pyrite was rounded or not.† In some of the specimens which I have examined the pyrite is substantially all in the form of well-rounded pebbles, issolated from one another by sand and secondary minerals. No one who has seen such specimens would admit for a moment either that the pyrite was not rolled or that it was fractured by movement in the rocks during upheaval. The pebbles have been worn round, and the detritus has been removed. In several cases they are externally converted into a brownish-black mineral, which is probably hematite, and the conversion must have taken place before the upheaval of the banket, for the specimens are blue and fresh. The pyrite pebbles measure on the average one-tenth of a millimeter in diameter. In some specimens the pyrites are densely crowded into layers and the pebbly character is less apparent. Some recrystallization may have gone on in these cases, but I did not succeed in finding the well-defined crystal outlines usual in embedded sulphurets. The pyrite pebbles in many cases contain numerous scattered

* South African Mines, by C. S. Goldman, 3 vols., 1895–96, vol. 3, plate 6.

† Les Mines d'or du Transvaal, 1896, pp. 306, 347.

particles of gold, which may be seen by very strong incident light. I have observed this both in my own slides and in Mr. Johns's suite.

The free gold in the matrix, like the pyrite, seems to be in two different conditions. Dr. Koch found the metal in minute crystals, or in irregular sharp-cornered, hackly aggregates. Mr. Pelikan observed it in irregular lumps, grains, and scales, which, in his opinion, correspond beyond a question to alluvial occurrences. According to Mr. De Launay, the gold almost always occurs as extremely minute scales, often so thin as to be translucent, very rare exceptions being aggregates of gold on the white quartz veins, small masses of free gold crystallized by secondary solution in the banket, and coatings on joint planes. Mr. Crosse also has found evidence of the existence of gold in a crystalline condition. In my slides the gold in the matrix corresponds most closely to Mr. De Launay's description. It appears in irregular flakes and scales, which often conform to the accompanying sand grains, as if pressure had molded the metal. The grains are not smooth, but neither have they either the crystalline appearance or the hackly surface of gold in vein quartz. The scales are often excessively thin, and pass over into mere yellowish-brown stains in which, by the help of direct sunlight, shining yellow points can be observed. The smaller scales of gold found on beaches are not ordinarily smooth, but they are smoother than those of the banket. I believe that pressure and the roughness of the surrounding detritus have determined their outlines to a large extent in the puddingstone.

Besides the more important minerals of the banket, Dr. Koch found in the matrix magnetite (also noted by Mr. Curtis), zircon, rutile, tourmaline, muscovite, chlorite, and a colorless highly refracting mineral not determined. Mr. Pelikan found biotite and a greenish mineral, perhaps identical with Dr. Koch's, which he suspects of being pyroxenic. Dr. Hatch notes marcasite, copper pyrites, blende, galena, ilmenite, and magnetite; he also records that Mr. Crosse has detected corundum by chemical means. I have repeatedly found pyrrhotite in the mines (for example, in the Crown Deep), but only in association with the white quartz veins referred to above. There is either magnetite or hematite among the pebbles of my slides, and zircons were observed, The main mass of the matrix consists, besides gold and pyrite, of sand grains, chlorite and sericite, and secondary quartz. It is interesting and important to compare this matrix with slides of the quartzite adjoining the banket, because many grains which might be interpreted as secondary in the matrix are there seen to be mere sand. In both quartzite and matrix it is apparent that

the sand grains have been largely attacked by sericite and that a portion of the irregularity of outline is due to this cause. The matrix also contains prisms, often grouped in fan-shaped aggregates, of a colorless secondary mineral, possibly an amphibole. The same or a similar mineral was noted by Koch and by Pelikan. Its determination is not essential for the purposes of this paper.

It is worth while to observe that the cement of the conglomerate is distinguishable from ordinary vein quartz as seen under the microscope. The crystallization of the cement has been accompanied by corrosion of arenaceous minerals, and the matrix is mingled with the products of this action as vein quartz seldom or never is. On the other hand, the cementing material of the conglomerate and that of the quartzite at a distance from the banket reefs appears to be indistinguishable under the microscope. In other words, the banket is a coarse heterogeneous quartzite.

It is well recognized on the Rand that, other things being equal, the coarser pebble carries the greatest quantity of gold. Usually the rich ore is heavily sulphureted, but this is not invariable. As a rule, the thinner portions of reefs are richer than thicker portions. It is usually the under portion of a coarse streak which is richest, but such a coarse streak is sometimes met with in the lower portion of a reef and sometimes in the upper portion. There is in this respect no general rule. It is said that the sandstone near the banket in rare instances carries gold. It is known, however, that in some alleged instances of this kind the gold was really confined to the parting between the sandstone and the banket. The banket is patchy. There are rich patches and poor ones, rich patches in poor ones, and poor patches in rich ones. Sometimes these patches have an elongated form, and then are often called "chutes." Opinions differ among managers as to whether there are on the Rand any real continuous chutes or channels, such as are almost invariably found in gold-bearing quartz veins. I could learn of no case which was an indubitable chute as distinguished from an elongated patch. Much less does any rule hold, as in most gold quartz districts, concerning the pitch of ore bodies on the surface of deposition. For the most part the bodies are certainly patches, and, if there are true chutes as well, two distinct types of deposit are present. The general uniformity of appearance and conditions militate against this view.

It has already been mentioned that the Lower Cape is intersected by numerous dikes, mostly of diabase or closely allied rocks, these dikes being connected in the most evident and

intimate manner with the formation of the white quartz seams which carry pyrrhotite and rarely pockets of gold. I made a special effort to ascertain whether the dikes are in any way connected with the tenor of the banket, and consulted many of the most experienced managers on the subject. There is, I believe, substantially no connection.* The ore at and near a dike is sometimes rich and sometimes poor; a single dike will intersect one stope, or one reef, at a point where the assays are high, and will cut another working or another stratum of puddingstone in a poor patch. The conditions are such as they would be if, after ore deposition were complete, the country had been disrupted and injected with dikes having no connection with the deposition of gold in the banket. Mr. De Launay came to precisely the same conclusion, and emphasizes it by an "assay plan" with the dikes drawn into it, and this diagram fully justifies his position.† Mr. John Hays Hammond, however, has very recently expressed his opinion that although it is generally true that there is no ascertained connection between the richness of the banket and these dikes, there are nevertheless notable examples of local enrichment due to the proximity of dikes.‡ Such exceptions seem to me hard to prove, for I think it would not be difficult to find other cases in which banket close to dikes is locally almost barren. Indeed I have heard of such occurrences, but cannot believe the local impoverishment due to the presence of the intrusive rock.

In the foregoing pages an attempt has been made to gather all the more striking facts which it is necessary to consider in testing the theories propounded to account for the deposition of gold on the Rand. One of them must be right.

The theory that the banket reefs are of alluvial origin, representing metamorphosed placers, was probably the earliest to be suggested, and was held as long ago as 1887, when gold production first began. Who first advocated this solution I am unable to state. It has been supported in 1891 by Mr. De Launay, who has since adopted another view, by Mr. Pelikan in 1894, and by Prof. F. Zirkel.

In 1888 Mr. W. H. Penning§ was led, mainly by the character of the gold (which he describes as occurring in sharp grains, not waterworn), to state: "I am convinced that it was deposited—at the same time the gravels were being accumulated—from water holding gold in solution." This is the opinion ex-

* Messrs. Hatch and Chalmers find no reliable evidence that dikes have acted beneficially on the tenor of the reefs. The Gold Mines of the Rand, 1895, p. 72.

† Op. cit. p. 324.

‡ Engineering Mag., Feb. 1898, p. 746.

§ Jour. Soc. Arts, London, vol. 36, 1888, p. 437.

pressed by Mr. De Launay in his latest work, 1896. Stelzner also inclined to a similar opinion.*

In discussing Mr. Penning's paper, Mr. W. Topley suggested that the water, which percolating through the already formed conglomerates deposited the gold, may have been at a high temperature. In 1890 my friend, Mr. J. S. Curtis, published a paper† on the banket, in which he states that Mr. Gardner F. Williams, now manager of the Kimberley diamond mines, considered the gold in the conglomerate as not alluvial but quartz gold, deposited after the upheaval of the strata. Mr. Curtis accepted this view, considered the deposits as closely resembling lodes, and referred the impregnation of the conglomerates to the action of the dikes. This opinion is based on the angular character of the gold and on the presence of pyrite both in the banket and in the dikes. Had the iron sulphide of the banket been alluvial, Mr. Curtis says, "there would have been pebbles of pyrites." Of course the large proportion of rounded pebbles of pyrite in the banket was then unknown. Mr. Curtis explained the fact that gold is not found in the sandstone by the relative porosity and openness of the conglomerate. The view of the deposits first distinctly expressed by Mr. Curtis is that to which Dr. Koch leans, and which is adopted by Messrs. Hatch and Chalmers, and by almost all the engineers on the Witwatersrand. Messrs. Hamilton Smith and John Hays Hammond consider a portion of the gold detrital and a portion as a deposition from solution after the uplift of the rocks.

None of the theories are free from objections, real or specious. The impregnation theory implies that there must be deep fissures through which the auriferous solutions obtained access to the once-barren banket beds, and that the solutions permeated the coarse beds to the practical exclusion of the finer sandstone strata. A system of fissures such as would be needed to convey metalliferous solutions certainly exists in the dikes and faults so abundant on the Rand. There are also less-pronounced partings or joints, often nearly parallel to the conglomerate beds. These last are very important in stoping the ore, and they are well known to all managers. All of these dislocations were produced during the upheaval of the beds from a nearly horizontal position into that which they now

* In 1894 Messrs. Schmisser, Stelzner, Suess and Zirkel testified before the Silver Commission in Berlin. The first two regarded it as an open question whether the gold of the banket is detrital or a chemical precipitate contemporaneous with the formation of the beds of puddingstone. The others were convinced that it is detrital, Zirkel adding that the deposits had undergone subsequent chemical metamorphism. (Kommission behufs Erörterung . . . des Silberwerths. Berlin, 1894, pp. 594–95, et passim.)

† Eng. and Min. Jour., vol. 49, 1890, p. 200.

occupy. The gold in the banket is not distributed in any apparent relation to the dislocations. Not only do the dikes cut the reefs in poor and rich patches indiscriminately, as was pointed out above, but such of the dislocations as are in sandstone or in quartzite are, as a rule, absolutely barren. The fissures are also almost altogether wanting in some localities where the ore is nevertheless of good grade. This is the case in portions of the Geldenhuis Deep and of the Simmer and Jack. In these mines there is often an inconvenient absence of any partings to which stoping can be carried, and this "freezing" is not attended by any falling off in the assays. On the other hand, the white quartz veins are manifestly related to the dikes, often starting from them or accompanying them, and themselves not dislocated by the fissure system to any greater extent than is easily accounted for by slight renewals of movement postdating the main upheaval. The white veins, however, cut and fault the banket, but without enriching or impoverishing it. The only natural conclusion is that the dikes and white veins postdate not merely the formation of the conglomerate, but the deposition of gold in the banket. The deep fissures which afforded channels for the ore-bearing solutions might be narrow, as a rule; but it is hardly possible that all of them should be so, and it is most improbable that the ore which they contained should not be rich, as rich as the banket would be if all the pebbles were removed from it. Now, no such "rake veins," as they would be called, have been met with on the Rand.

If the solutions rose through "rake veins," they would permeate all accessible permeable strata and partings. Now, it seems to be generally assumed that a conglomerate without matrix would be much more permeable to fluids than a sandstone. This is true if only rapid currents, such as might be impeded by fluid friction, are to be considered. There is no probability, however, that ores are deposited from rapid currents. For slow currents fluid friction is a vanishing quantity, and then the permeability of a given rock may be considered as measured by the interstitial space. Now, the interstitial space in a conglomerate composed of pebbles of various sizes is really less per cubic foot than that of a fine but even-grained sandstone. If the material is of absolutely uniform grain, the interstitial space is wholly independent of the size of the component particles, and cannot fall below 26 per cent. It is a fact well known to mill men that a cubic foot of sized tailings weighs less than a cubic foot of unsized tailings. Sandstones used for building in some cases contain over 20 per cent. of voids, and highly indurated sandstones contain 4 or 5 per cent.

Even if the ore-bearing currents were so rapid as to permeate the pebbly beds more freely than sandstones possessing the same interstitial space, the smaller resistance of the former would not confine ore deposition to the coarser mass. Permeation would take place in any direction in inverse proportion to the resistance in that direction, and the auriferous fluid would escape from the pebble-layer as sewage does from porous underground distributing pipes. It follows, then, that the sandstones as well as the conglomerates should have been impregnated when soaked in an auriferous solution, and to approximately an equal extent, while as a fact the sandstone does not contain one one-thousandth part of the gold. The impregnation theory would, furthermore, seem to involve the presence and the prevalence of chutes in the banket. There is no doubt that most of the gold occurs in patches which are distinctly different from chutes, and many engineers are confident that real chutes are absent. Much of the pyrite is in the form of minute waterworn pebbles, and much of the gold is inclosed in the pyrite, indicating a common origin for the two minerals. This fact is regarded by De Launay as fatal to the impregnation theory, and, indeed, it seems impossible to reconcile this mode of occurrence with the hypothesis.

Had the gold been deposited from solution one or another of the characteristics of various deposits might well have been absent or obscure. It is difficult to believe that all should have been obscure if not totally absent. The evidence in such a case must be considered cumulatively.

The strength of the impregnation theory lies in the fact that some of the gold and of the pyrite appears to be crystallized, as if deposited in place. A portion of the observed phenomena seem certainly secondary. Below water level, or "in the blue," visible gold is very rare* on the Rand. In the oxidized upper levels it was much more frequent, and free gold was often found in the cavities from which pyrite had disappeared by oxidation. This is, of course, a very common phenomenon at the croppings of auriferous deposits, and can be accounted for only by the recrystallization of gold attending the oxidation of pyrite. The modus operandi is also pretty clear. Ferric sulphate is a weak solvent for gold, and iron sulphate is one of

* "Very rare" is a relative term. Mr. Hammond takes exception to my statement, which he probably interprets in a more superlative sense than I intended it. Hatch and Chalmers, who were certainly thoroughly familiar with the ore, assert that, as a rule, the gold "is disseminated through the ore in finely divided particles which are rarely of sufficient size to be visible to the eye" unless the ore is first panned. I am quite aware that in most of the mines a speck of gold is seen from time to time and that there are some specimens in which it is abundant. The point of the statement in the text is that *more* visible gold occurred in the oxidized zone than beneath it.

the products of decomposition of pyrite. Recrystallization is a process which goes on in the presence of weak solvents. Recrystallization of rock components is a very common thing, and the ordinary phenomenon called metamorphism is substantially recrystallization. The quartzite walls of the Main Reef are in part recrystallized sandstones, and recrystallization of silica has certainly taken place in the banket. Some recrystallization of gold and pyrite in the blue may very probably have occurred as an incident to general metamorphism or to the formation of the white veins. Hence the impregnation theory is not the only one which will account for the state of one portion of the gold and pyrite, and the fact that it could explain this state is insufficient to outweigh the many objections to the theory.

On the whole, then, it appears to me that this theory is untenable. It is popular with engineers accustomed to quartz veins, partly because it involves a close analogy between the Rand deposits and the more familiar type of gold deposit.

The theory maintained by Mr. De Launay in his latest work is that the sea in which the banket was deposited was a saturated solution of gold and pyrite. These minerals were precipitated as the banket accumulated, a part of the pyrite being at the same time waterworn. This theory is an elaboration of Mr. Penning's. It avoids some of the objections to the impregnation hypothesis. The absence of rake veins and well-marked chutes is consistent with the scheme of Messrs. Penning and De Launay, and it would account fairly well for the patchiness of the reefs. Mr. Penning was driven to it by the angularity of the gold; Mr. De Launay, by the supposed importance of the rarity of gold in the pebbles.

The precipitation theory, however, is by no means free from objections, chief of which is that it gives no account of the most important feature of the deposits, namely, the association of gold in largest quantity with the coarsest banket. One would expect to find the sands at least as much mingled with the auriferous precipitate as the banket. Precipitates are usually thrown down in a fine state of division. How is it, then, that the currents which swept away all mud and fine sand did not also carry off the crystals of gold and pyrite before they had time to reach considerable dimensions? To meet this evident objection Mr. De Launay makes the following statement:

Pour tenir compte de ce fait charactéristique que l'or est presque-exclusivement dans les conglomérats et non dans les grès intermédiaires, on admettrait l'influence d'une préparation mécanique ayant concentré l'or et la pyrite, en leur qualité d'éléments

lourds, avec les galets les plus gros, comme cela s'est passé pour tous les dépôts d'alluvions aurifères.

Thus this geologist supposes a relatively quiet deposition of gold and pyrite from sea water in unsorted material, followed by a natural concentration. Now, sorting begins the moment that detritus from the land reaches the sea. I perceive no opportunity for the supposed quiet precipitation of gold and pyrite; nor do I understand why precipitation, if it takes place at all, does not continue during the sorting process, so that the sands eliminated from the pebbly material would continue to be enriched by precipitation.

The fundamental hypothesis of a sea highly charged with gold and pyrite seems to me extremely improbable. Had the ocean at any time been so charged, the mineral would, as Mr. De Launay says, be precipitated with extreme ease. How then could the ocean become highly charged? It would seem that the gold and pyrite going into solution, say at the mouth of some submarine solfataric vent, must be thrown down almost immediately and close to the point at which solution took place. An almost uniform distribution of gold along a coast known to be at least 30 miles in length would then be impossible. Again, if the ocean ever was so powerful a solvent for gold, why are there not many and indubitable cases of deposits formed by this method?

The advantages of the precipitation theory over the simple detrital theory are, as I understand Mr. DeLaunay, that the former hypothesis explains why there is no gold or pyrite in the pebbles and why the gold is not substantially all on the foot wall of the reefs. These advantages are by no means substantial ones, as will presently appear.

As has been noted above, pebbles which carry crystallized pyrite and other sulphurets disseminated through the quartz, and not on fissures of any sort, are fairly abundant on the Rand. Gold is also known in the pebbles. Some writers consider it very strange that if the pebbles came from auriferous quartz veins, gold-bearing pebbles are not more abundant.* As a matter of fact, in the auriferous river gravels of California and Venezuela, pebbles showing visible gold are extremely rare. Even in the vast exposures of the hydraulic washings one might spend weeks in the vain search for a specimen. In the sluices, however, small pieces of auriferous quartz may be found with the gold, separated by the concentration process from thousands of tons of barren pebble. On the auriferous beaches of California, Oregon, and Alaska, such pebbles seem

* Mr. Curtis did not adduce the rarity of gold-bearing pebbles in favor of the impregnation theory, no doubt because of his familiarity with California gravels.

to be still rarer than in the river gravels. Thus the rarity of gold-bearing pebbles on the Rand is such as should be expected from analogy if the deposits belong to the class of placers.

The presence of crystallized gold and pyrite is by no means unaccountable on the same theory. Even in the Tertiary gravels of California recrystallization of sulphurets is now in progress, and it is probable that recrystallization of gold also has taken place to some extent. On the Rand it is certain that solutions capable of dissolving gold to some extent have been present below water level at some time since the original deposition. These accompanied the formation of the white quartz veins which cut the banket beds and which occasionally carry a little gold. The same solutions must have been capable of dissolving pyrite. The solvent fluids were probably hot waters containing sulphides of the alkalies and carbonates. Such waters dissolve gold and sulphurets, and they almost invariably accompany eruptive activity such as is manifested in the dikes of the Rand. Now, recrystallization being due to the action of fluids which exercise a feeble solvent power, it would be extremely remarkable (taking the existence of the white veins into consideration) if the gold and pyrite of the banket showed no evidences of recrystallization. It is quite as easy to account for recrystallization of the gold and the pyrite as for the conversion of the sandstone into quartzite.

The objection to the theory under consideration, that the gold is not uniformly found on the foot wall of the reef, is entirely without weight. In auriferous *river* gravels, indeed, most of the gold is found either on bed rock or on layers of pipeclay; but the banket is not a river deposit. As has been explained already, river gravels are distinguishable both by the form of the pebbles and by their imbrication or "shingling" from marine gravels, to which class those of the Rand belong. The deposits are therefore comparable with the auriferous beach deposits of the Pacific Coast or of New Zealand, and not with the river gravels of the Sierra Nevada. In the beach gravels the gold is found at the bottom of the layer of material set in motion by the last wave or current by which the mass has been agitated. Hence the beach deposits consist of stratified masses of gravel and sand in which the gold is for the most part confined to those layers which are composed of heavy particles, but not necessarily to the bottom of such layers, for if these have any considerable thickness, the upper part may be disturbed without movement in the lower portion. Thus thin layers of rich gravel, underlain and overlain by substantially barren layers, are very characteristic of gold-bearing beach deposits.

On the Pacific Coast the gold is commonly associated with

black sands, consisting largely of magnetic iron oxide or titanic iron ore. On the Rand, magnetite, though not absent, is relatively rare. It does not follow that the deposits of the two regions are not similar. The magnetite on the Pacific beaches does not originate to any extent in the gold-quartz veins, but in country rock. If the country rock happened to be poor in magnetite the sands would not be black. Such seems to have been the case in the Jurassic gold-bearing marine conglomerate of Placer County, California. Again, the magnetite may have been in part converted into pyrite by the sulphur-bearing solutions accompanying the intrusion of the dikes.

The beach sands of the Pacific Coast of North America and those of New Zealand form along the shores of extensive gold-bearing regions. It is natural that they should so form; it would be difficult to comprehend their entire absence, and it is hard enough to understand why they are not more abundant. What has become of the immense quantity of gold swept away by erosion from the western slope of the Sierra Nevada and the auriferous territory of northern California? It has certainly been carried to the sea, and, as a heavy metal, some of it has been left along the coast in the beach sands. The aggregate quantity of gold in the sand is very great, but I see no probability that it represents more than a small fraction of the gold which has been scattered by Nature's hydraulic process. The only answer is that the metal has been so triturated, so "floured," that it has been swept away into the abyss of the Pacific and perhaps partly dissolved in the waters of the ocean. Just as very fine gold can not be saved in a sluice, so still more finely comminuted gold must remain suspended almost indefinitely in ocean currents.

Now, at the time of the formation of the conglomerate the Witwatersrand lay along the shore of an extensive auriferous area, presenting belt after belt of quartz veins striking in a direction nearly parallel to the coast. The drainage probably cut across this area, bringing down auriferous detritus. The streams certainly brought down vein quartz from a gold-bearing country. This supply was more abundant at some times than at others, the variation probably representing fluctuations in the gradual upheaval of the land area. It is clear that vigorous currents swept the shore, for otherwise such accumulations of conglomerate could not have been formed. Here, then, there were all the conditions for the formation of beach placers. It might have been predicted *a priori* that, if littoral deposits could be found within a moderate distance to the southward of the area of Mashonaland, Matabeleland, and the northern Transvaal, they would be nearly certain to show some alluvial gold.

It has been argued that if the deposits of the Witwatersrand are ancient beaches they are substantially unique. It is certainly true that they are the richest of such deposits ever known, but geologically and qualitatively they by no means stand alone. Europe, America, Australia, and New Zealand all possess auriferous, marine gravels of pre-Tertiary age. Ancient river gravels would be preserved only under exceptional circumstances, and it is doubtful whether a single case of pre-Tertiary gold-bearing river gravels is yet known. It is interesting to compare other old gold placers with the deposits of the Witwatersrand, and for that reason notes on some of them were added to my other paper. They certainly reënforce the argument for the alluvial origin of the gold in the banket, and it may be noted that nearly all of these deposits lie in the regions known to contain gold-quartz veins older than the marine strata.

Let it be assumed for the sake of argument that the banket really represents a marine placer of early Paleozoic age, formed off the shore of an extensive gold-bearing region, and since injected with dikes. One would then expect to find the gold in the coarser streaks of the resulting conglomerate and on the lower side of such streaks. The reef would extend for many miles and perhaps for many hundreds of miles. The tenor would depend in part on the strength of the currents sweeping along the coast, and in part on the quality of the material fed into the sea at the different points, or at the same point during different seasons. Hence, conglomerate of a given coarseness would be richer at some points than at others, and there might be almost barren portions or beds, but the distribution would be in patches, not in chutes. The gold would almost all be finely divided, for nuggets would commonly remain in the rivers. Pyrite would almost certainly appear in the sands, but experience shows that gold-bearing pebbles would be rare. When the conglomerate was upheaved, injected with dikes, and metamorphosed, it would be found that the dikes sometimes cut poor patches and sometimes rich ones, their disposition having nothing to do with the original distribution of the gold. The sandstones would be converted into quartzites, and recrystallization of gold and pyrite would occur to some extent. In short, it seems to me that deposits exactly analagous to those of the Rand must form in this way, while in some details the composition of the banket would doubtless depend on the lithological character of the back country.

Thus, it seems to me that there are no valid objections to the theory of marine placer origin and no noteworthy features left unexplained by this theory, while so much can not be said

of either the impregnation or the precipitation theory. The beach deposits of the Pacific form an excellent instance of such marine placers, although they are not so rich as those of the Rand. On the other hand, no case is known of an extensive gold deposit which is certainly an impregnation in sand or gravel, nor is there an established case of marine precipitation.

There seem to be no other possible theories besides those discussed, but Messrs. Smith and Hammond are of the opinion that the gold is partly detrital and partly in place in the banket. Speaking with exactness, I agree with them, for, as has been mentioned, the white quartz veins are not absolutely barren. To my mind, however, it seems conclusively proved that only a minute fraction of 1 per cent. of the gold has this origin, for I see no reasonable evidence that any portion of the gold excepting that to be found in the white quartz seams is untransported.

On the theory which I have adopted the auriferous banket should be found to stretch along a line of ancient coast bounding an area in which gold-bearing quartz veins were rich and numerous. How large this area may have been, and therefore how long its ancient coast was, it is as yet impossible to say; but the indications are that the area was extensive and the coast long. Doubtless some portions of the coast will furnish only banket too poor to work, but until the Lower Cape formation has been traced across the continent of Africa other spots as rich as the Rand may be hoped for.

Washington, D. C., February, 1898.

ART. XXVIII.—*The Estimation of Manganese as the Sulphate and as the Oxide;* by F. A. GOOCH and MARTHA AUSTIN.

[Contributions from the Kent Chemical Laboratory of Yale University—LXVII.]

THE estimation of manganese by the conversion of salts of that element with volatile acids to the form of the anhydrous sulphate by the action of an excess of sulphuric acid, evaporation, and gentle heating was formerly a recognized procedure. On the authority of Rose,* however, this method was set aside on account of the supposed difficulty of removing the excess of acid without disturbing the composition of the normal salt. Thus, Oesten, working under Rose's direction, obtained, upon submitting the crystalline hydrous sulphate $MnSO_4 . 5H_2O$ to heat, results which may be summarized and compared with the results obtained by Rose's sulphide method (the ignition of the residue with sulphur in hydrogen) as follows:

$MnSO_4 . 5H_2O$ taken. grm.	$MnSO_4$ found. grm.	Theory. grm	Error. grm.	MnS found. grm.	Theory. grm.	Error. grm.
1·659	1·043†	*1·037*	*0·006* +	0·597	0·595	*0·002* +
	1·023‡		0·014 —			
1·481	0·934†	*0·926*	*0·008* +			
	0·905‡		0·021 —			
	0·725§		0·201 —			
1·430	0·880‡	0·893	0·013 —	0·509	0·512	*0·003* —

† Ignited gently. ‡ Ignited at low red heat. § Ignited at strong red heat.

The residues remaining after the gentle ignition of the sulphate weighed apparently several milligrams more than should have been the case if the salt had been reduced to the normal anhydrous sulphate. At higher temperatures the sulphate turned brown and lost altogether too much weight. A comparison of the errors of the process in which the ignition was at low temperature with those of the sulphide process would seem to justify Rose's rejection of the former method for the latter. Upon recalculating these results, however, using atomic weight in use at present—viz: Mn = 55, S = 32·06, O = 16—it becomes plain that the errors of the two processes, as shown in Oesten's work, are not very different numerically, though with opposite signs.

$MnSO_4 . 5H_2O$ taken. grm.	$MnSO_4$ found. grm.	Theory. grm.	Error. grm.	MnS found. grm.	Theory. grm.	Error. grm.
1·659	1·043	1·039	0·004 +	0·597	0·599	0·002 —
1·481	0·934	0·928	0·006 +			
1·430				0·509	0·516	0·007 —

* Ann. d. Phys. u. Chem, cx, 125.

The most uncertain element in these experiments is the difficulty, well-recognized at present, of getting the hydrous manganous sulphate, upon which the experiments were made, in a perfectly definite condition of hydration.

Volhard* subsequently studied the sulphate process, and showed that manganous sulphate may be dehydrated, separated from an excess of sulphuric acid, and brought into definite condition for weighing as the anhydrous salt by careful and protracted heating over a special device of his own—a ring burner enclosed in a sheet-iron casing. Thus, on evaporating and dehydrating a solution of pure neutral manganous sulphate, Volhard obtained the results recorded in the following statement:

Residue of $MnSO_4$ left by evaporation and dehydration	0·1635
" after treatment with 3 drops of H_2SO_4 and heating 3 hours	0·1635
" after heating 2 hours	0·1638
" after treatment with 4 drops of H_2SO_4 and heating $2\frac{1}{2}$ hours	0·1635
" after heating 3 hours	0·1635

Similar results were obtained on evaporating with sulphuric acid and igniting in like manner an aqueous solution of manganous chloride. Volhard's recommendation of the method has not secured for it the acceptance which its simplicity and exactness would seem to demand—possibly because the periods of ignition appear to be considerable and the manner of heating special.

In our own experiments with the sulphate process we have found that special apparatus is unnecessary, that the time of treatment may be short, and that the process is in every respect simple as well as very exact. We took for a starting point manganous chloride prepared in the manner to be detailed. An aqueous solution of the so-called pure manganous chloride of commerce was boiled with pure manganous carbonate (to throw out aluminum, iron and chromium), filtered, and precipitated with ammonium sulphide. The precipitate thus obtained was dissolved in a very slight excess of hydrochloric acid (to leave behind possible traces of nickel, cobalt, and copper), the solution was boiled to expel hydrogen sulphide and precipitated with sodium carbonate. The manganous carbonate thus thrown down was boiled repeatedly with successive portions of water, and washed until the washings were free from chloride. The greater part of this purified carbonate was dissolved in the least possible amount of pure hydrochloric acid, the reserved portion of the carbonate was added, the mix-

* Ann. d. Chem., cxcviii, 328.

ture was boiled, and the solution of the purified and neutral manganous chloride was filtered from the excess of undissolved carbonate. Definite portions of this solution were precipitated with silver nitrate, and from the weight of the silver chloride thus obtained the amount of manganous chloride present was calculated. Portions of the solution thus standardized were drawn, for our experiments, from a burette into a weighed platinum crucible, sulphuric was added in amount more than equivalent to the manganese, the solution was evaporated on the water-bath until the water was removed, and then, supported by means of a porcelain ring, or triangle, within a larger porcelain crucible used as a radiator so that the bottom and walls of the one were distant from the bottom and walls of the other by an interval of about 1^{cm}, the crucible was heated more strongly. The outer porcelain crucible may be heated over a good Bunsen flame to a red heat without risk of overheating the manganese sulphate within the inner crucible, and the ignition may proceed as rapidly as is consistent with the avoidance of mechanical loss by spattering. The results obtained by treatment of equal portions (50^{cm^3}) of the same solution are given, together with the results of standardizing the solution by precipitation with silver nitrate, in columns A of the following table. In the other columns are given comparative results got in the treatment of equal portions of several other solutions employed subsequently in other work.

$MnSO_4$ calc'd from AgCl found in 50^{cm^3} of solution A.	$MnSO_4$ found by treatment of 50^{cm^3} of solution A with H_2SO_4.	$MnSO_4$ found by treatment of 50^{cm^3} of various solutions with H_2SO_4.					
grm.	grm.						
A	A	B	C	D	E	F	G
(1) ·3518	(1) 0·3513	(1) 0·3100	(1) 0·3256	(1) 0·3534	(1) 0·3524	(1) 0.3355	(1) 0·5475
(2) ·3512	(2) 0·3514	(2) 0·3104	(2) 0·3254	(2) 0·3543	(2) 0·3520	(2) 0·3357	(2) 0·5476
	(3) 0·3518	(3) 0·3096					

These results show plainly that the process of estimating manganese in the form of the anhydrous sulphate is both simple and accurate.

The estimation of manganese as the manganoso-manganic oxide Mn_3O_4, has been so frequently criticized unfavorably that the method may be said to have passed from very general use excepting in certain cases in which the directness of the process is a temptation to incur the risk of some uncertainty. The production of the other oxides of manganese in definite condition is thought to be even more uncertain. Manganese dioxide,

MnO_2, begins, as Wright and Menke have shown* to lose oxygen at a temperature (about 210° C.) to which the hydrated oxide must be heated to free it from water, or very nearly that at which the nitrate is converted into the dioxide; so that the chance of producing an undecomposed dioxide by the ignition of the hydrated dioxide (the form in which the dioxide generally appears in analytical processes), or of the nitrate, is small. Manganic oxide, Mn_2O_3, is produced, it is said, from the other oxides by ignition at a low red heat under the ordinary conditions. The manganoso-manganic oxide, Mn_3O_4, forms, presumably, when an oxide of manganese is submitted, under ordinary atmospheric conditions, to the high heat of the blast-lamp. If the proportion of oxygen in the surrounding atmosphere is reduced below the normal, the conversion of Mn_2O_3 to Mn_3O_4 goes on very easily, as Dittmar has shown,† at a temperature between the melting points of silver and aluminum, while if the proportion of oxygen in the surrounding atmosphere falls much below the normal, the reverse change, from Mn_3O_4 to Mn_2O_3, tends to take place at the same temperature. It is not surprising, in view of these phenomena, that the estimation of manganese as the oxide Mn_3O_4 should have fallen into disrepute; and yet, if the condition most favorable to the production of that oxide—a low proportion of oxygen in the surrounding air—can be maintained during the ignition, it is not impossible that the indications of the process might prove to be, under the conditions, reasonably accurate. Now, this may be exactly the condition of affairs when the ignition takes place ordinarily; for, if the products of combustion displace the ordinary air about the crucible, the proportion of oxygen about the oxide falls to a low limit. We have made the experiment of enclosing the ignited crucible within an inverted crucible, so that the products of combustion should be held immediately about and above the ignited oxide, but our experience has shown that the object in view is attained, apparently, quite as well when the ignition is so arranged that the crucible simply rests well within the upper part of the flame of a strong Bunsen burner, or blast-lamp, in such manner that an oxidizing flame covers nearly the entire wall of the crucible.

In the following experiments we have put to the test this matter of getting definitely the different oxides of manganese. We started with a known amount of pure anhydrous sulphate, prepared from the pure chloride in the manner previously described. This sulphate was converted by ignition into the oxide—presumably the oxide Mn_3O_4—the containing crucible being well within the upper flame of a powerful burner.

* Jour. Chem. Soc., xxx, 775. † Jour. Chem. Soc., xvii, 294.

$MnSO_4$ taken. grm.	MnO_2				Mn_2O_3				Mn_3O_4				$MnSO_4$		
		Found. grm.	Theory. grm.	Error. grm.		Found.	Theory.	Error.		Found.	Theory.	Error.		Found.	Error.
0·3712									I	0·1880	0·1876	0·0004 +			
	II	0·2114	0·2138	0·0024 −	III	0·1975	0·1954	0·0021 +							
	IV	0·2137		0·0001 −	V	0·1959		0·0005 +							
	VI	0·2147		0·0009 +	IX	0 1986		0·0032 +							
	VII	0·2147		0·0009 +	X	0·1957		0 0003 +	XI	0·1881		0·0005 +			
	VIII	0·2138		0·0000 ±											
	XII	0 2145		0·0007 +	XIII	0·1948		0·0006 −	XIV	0·1877		0 0001 +			
	XV	0·2115		0·0023 −	XVI	0·1939		0 0015 −	XVII	0·1872		0·0004 −			
	XVIII	0·2158		0 0020 +	XIX	0·1942		0·0012 −	XX	0·1899		0·0023 +	XXI	0·3709	0 0003 −
0·6436									I	0·3247	0·3252	0·0005 −			
	II	0·3443	0·3707	0·0264 −											
	III	0 3704		0 0003 −	IV	0·3372	0 3387	0 0015 −	V	0·3245		0·0007 −			
	VI	0·3705		0 0002 −	VII	0·3367		0·0020 −	VIII	0·3244		0·0008 −			
	IX	0·3597		0·0110 −											
	X	0·3719		0·0012 +	XI	0·3369		0·0018 −	XII	0·3243		0·0009 −			
	XIII	0·3729		0·0022 +	XIV	0.3362		0·0025 −	XV	0·3244		0·0008 −			
	XVI	0·3690		0·0017 −	XVII	0·3366		0 0021 −					XVIII	0·6432	0·0004 −
													XIX	0·6432	0·0004 −
													XX	0·6437	0 0001 +

In the next step, this oxide was further oxidized by moistening it with nitric acid and heating the residue gently until the evolution of fumes ceased, the containing crucible being placed well above a porcelain crucible used as a radiator and heated so that only the bottom showed a faint red heat. In this process the attempt was made to arrest the ignition at the point where the anhydrous dioxide was produced. As the table shows, and as would be expected, this attempt was only occasionally and partly successful.

The residue of the last process was then submitted to a higher heat. The platinum crucible containing the oxide was placed within and touching the bottom of a larger porcelain crucible which was heated to redness. Under these conditions the temperature should not be too hot, and the products of combustion should naturally be thrown so far away from the oxide undergoing ignition that circumstances should be favorable for the formation of the oxide Mn_2O_3. The event proved that the attainment of the exact condition corresponding to the symbol Mn_2O_3 is a matter of some uncertainty.

Next, the oxide was subjected to the highest heat of a strong Bunsen burner (or in some cases, the broad flame of a blast lamp), the crucible being well surrounded by the products of combustion. The results of this treatment, it will be seen, agree, with a single exception out of ten experiments, reasonably well with the theory for Mn_3O_4.

By treating the final oxide with nitric acid and repeating the cycle of operations described, the observations of the phenomena were multiplied, until finally, the oxide formed last was treated with sulphuric acid, ignited in the manner previously detailed, and weighed as the anhydrous sulphate, thus showing that no significant loss of material had taken place in the series of manipulations. The table comprises the results of these experiments. The Roman numerals indicate the order of treatment.

The inference is plain that the estimation of the manganese in the form of the manganoso-manganic oxide, Mn_3O_4, is by no means to be considered utterly untrustworthy when the process is conducted in the manner described, though it must be recognized that an irregular result may occur occasionally. The danger of accepting such an irregularity as a correct indication may be eliminated to a very considerable extent if the precaution is taken invariably to moisten the ignited oxide with nitric acid, and ignite again. The indications of harmonious results thus got may be taken with a fair degree of confidence. However, it is, in our judgment, by far the wiser and simpler plan to convert an oxide of manganese obtained in course of analysis into the sulphate and to weigh the manganese in that form.

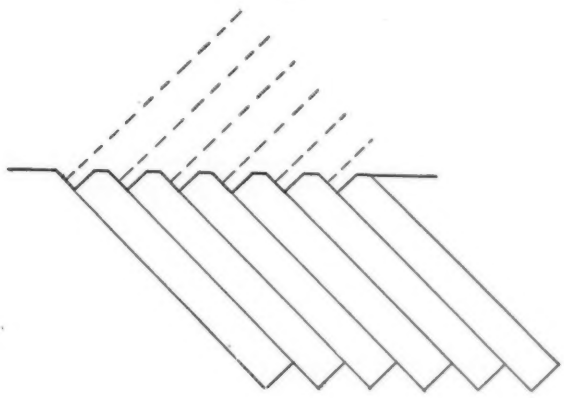
Art. XXIX.—*A Spectroscope without Prisms or Gratings;* by A. A. Michelson.

The resolving power of a diffraction grating is proportional to the product of the total number of lines by the order of the spectrum observed. But little effort seems to have been made to make a decided step in the direction of increasing the *order* of the spectrum observed, and this is doubtless because for a grating acting by *opacity* the brightness of the spectrum diminishes very rapidly as the order increases. This difficulty has been successfully overcome by ruling the lines in such a way as to concentrate the greater proportion of light in one spectrum, but so far as I am aware such attempts have been limited to the first, second or third spectrum and the results even here are somewhat fortuitous.

It seems nevertheless quite possible to construct gratings which shall throw a quite large proportion of the light in very high orders of spectra—say the hundredth—in which case the grating space must be of the order of a hundred waves or say twenty to the millimeter, instead of a thousand. The lines would have to be drawn with no more accuracy than before, and the grating could be completed in a very short time and temperature changes would have a much smaller effect than at present.

It may be that there are more serious practical difficulties in the way of such a ruling as is represented in fig. 1 than would

1.

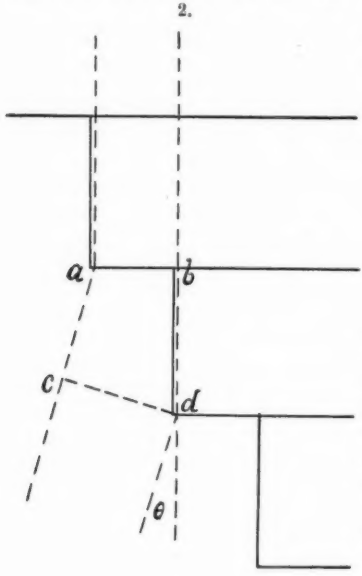


be anticipated. Especially may this be true if the greater part of the light is to be returned in the direction from which it

came; for that the grooves must be correspondingly deep, and the grating space would vary with the depth. Fig. 1 at once suggests a possible method of effecting the same result, by building up the steps by equal thicknesses of optical glass. Here the difficulty, even supposing the optical work to be practically perfect, would be the joining of the separate plates in such a way as to have always the same distance between them.

By using the same arrangement for transmission instead of reflection this difficulty is avoided—and there remains absolutely nothing but the difficulty of making a considerable number of plane-parallel plates of the same thickness—to an order of accuracy only one-fourth that required in the former arrangement, or even one-tenth of this if the other medium be water or oil instead of air.

Probably the surprising thing is the smallness of the number of plates required to give results which are comparable with those of the best gratings. This can be shown as follows:



let abd (fig. 2) be one step in the series of plates and let $ab = s$ and $bd = t$. If m is the order of the spectrum observed, $m\lambda = \mu . bd - ac$ or

$$m\lambda = \mu t - t\cos\theta + \delta\sin\theta .$$

$$d\theta/d\lambda = \frac{m - t\frac{d\mu}{d\lambda}}{t\sin\theta + \delta\cos\theta}$$

$$d\theta_1/dm = \frac{\lambda}{t\sin\theta + \delta\cos\theta}$$

and if $\delta\theta$ is the displacement corresponding to $\delta\lambda$ and $\delta\theta_1$ that corresponding to $\delta m = 1$, assuming Cauchy's formula $\mu = a + b/\lambda^2$. and taking the approximate value of $m = (\mu - 1)t/\lambda$, we have

$$\delta\theta/\delta\theta_1 = [(\mu - 1) + 2(\mu - a)]\frac{t}{\lambda}\cdot\frac{\delta\lambda}{\lambda}.$$

For ordinary glass the coefficient of t/λ is approximately equal to unity; so that if $\frac{\delta\lambda}{\lambda} = \cdot 001$ as in the case of the two sodium lines, and $t = 5^{mm} = 10000\,\lambda$, then $d\theta = 10\,d\theta_1$, that is, the sodium lines would be separated by ten times the distance between the spectra.

The resolving power of such a combination is mn, exactly as in the case of gratings; so that with but *twenty* elements 5^{mm} thick and hence $m = 5000$ the resolving power would be 100000, which is about that of the best gratings.

The experiment was actually tried with but *seven* elements, placed between a collimator and an observing telescope and the collimator slit illuminated with light from a sodium flame. The images were so distinct that the broadening of the lines could be very easily detected, and the Zeeman effect was readily observed when the sodium flame was placed in a magnetic field.

It is important to note that the resolving power is independent of the number of plates but depends only on the total thickness, and the only advantage in a large number of elements is the greater separation of the spectra. The overlapping of spectra is doubtless a disadvantage, which however could be overcome by a preliminary analysis; and for the examination of single lines and especially in the investigation of effects of broadening, shifting or doubling of lines, the method seems especially well adapted. A battery of twenty plates has been ordered and it is hoped that further results will be obtained within a few weeks.

Ryerson Physical Laboratory,
University of Chicago.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On an Electrochemical method for changing an Alternating into a Direct Current.*—It has long been known that when an aluminum plate is made the anode in an electrolytic cell, the oxygen set free upon this plate produces there a coating of oxide which greatly increases the resistance of the cell. Hence a cell having such an electrode acts like a trap, the current being permitted to flow freely when the aluminum plate is made the cathode, while when it is the anode the current is very feeble. Graetz has now proposed to utilize such cells for the purpose of changing alternating currents into direct ones. For this purpose a number of such cells are arranged in series, the number being so chosen that the polarization at the anode is either equal to or is greater than the current-pressure. Under these circumstances the current in that direction for which the aluminum plate would act as the anode is greatly diminished, while the opposite current passes freely. The issuing current therefore is practically a current in one direction.—*Ann. Phys. Chem.*, II, lxii, 323–327, September, 1897. G. F. B.

2. *On the Electrochemical Equivalent of Carbon.*—It has been noticed that in electrolyzing liquids evolving oxygen, using carbon as the anode, this carbon is acted upon chemically, the character and extent of this action depending upon the electrolyte employed. Thus Coehn has determined that when a current of 0·12 ampere is sent through six electrolytic cells having pure carbon anodes and platinum cathodes, the electrolyte being sulphuric acid diluted with 1, 10, 20, 50, 100 and 500 volumes of water, for ten hours, the most concentrated acid remains colorless, the most dilute becomes dark brown, while the intermediate solutions have intermediate shades; at the same time there being considerable mechanical disintegration. At higher temperatures this disintegration becomes less, while the electrolyte is still more deeply colored. Thus at 100°, in a solution made up of equal volumes of sulphuric acid and water, the mechanical disintegration becomes inconsiderable. The author determined the loss of weight of a carefully purified carbon anode under these circumstances, and obtained the value 3·5 as the electrochemical equivalent of carbon; but this number is probably too high, as some mechanical loss had taken place. He then made a number of experiments at the ordinary temperature, using sulphuric acid diluted variously with from 10 to 500 volumes of water, the fragments of carbon mechanically separated being collected and weighed, and their weight subtracted from the total loss of the anode. The value of the electrochemical equivalent of carbon thus obtained varied from 2·7 to 3·0. It thus appears that this number is independent both of the concentration of the acid and

of its temperature, although the action at first appears to be materially influenced by these conditions.—*Zeitschr. Electrochem.*, iii, 424–5, April, 1897. G. F. B.

3. *On the Use of the Copper Voltameter.*—Additional experiments have been made by FOERSTER upon the copper voltameter and the best means of avoiding the errors to which it is liable. While the copper sulphate solution should be concentrated in order to avoid the deposition of the metal in the pulverulent form, yet it increases the concentration of the cuprous ions; although, owing to their oxidation by the air, the solution never becomes saturated with these ions. Hence when the solution is exposed to the air the quantity of copper deposited is too small, particularly when the current density is small. The fact that a copper plate in an acid solution of copper sulphate is most strongly attacked at the surfaee of the liquid, is thus explained. If sulphuric acid be added to the copper sulphate solution, while it diminishes to some extent the concentration of the cuprous ions, its presence is of much more importance in preventing the separation of cuprous oxide, which, owing to the hydrolysis of cuprous sulphate, takes place in neutral solutions. If this cuprous oxide be deposited on the cathode, it not only increases the weight of the deposit but it causes inequalities in conductivity and hence gives rise to the production of cuprous ions where the current density is smallest. Again, a saturated sulphate of copper solution cannot be used because the solubility of this salt is diminished by the presence of the acid and hence causes the deposition upon the anode of the salt itself, producing an increase in resistance. He recommends as a suitable solution, one containing 125 grams of $CuSO_4(H_2O)_5$ and 50 grams of H_2SO_4 to the liter. When air is present no more copper is dissolved by the strongly acid solution than by the weaker one; a normal solution of copper sulphate, normal also as to the sulphuric acid, dissolving 17 milligrams of copper, while a solution containing only one thousandth of an equivalent of acid, under the same conditions, dissolved 15 milligrams. For very weak currents the author uses a closed voltameter containing a solution of copper sulphate, one-tenth or even one-twentieth of a gram-equivalent, and one gram-equivalent of sulphuric acid; a slow current of pure hydrogen being continuously passed through it. This reduces to a minimum the formation of cuprous ions, while their conversion at the anode into cupric ions is prevented by enclosing this anode in parchment paper. The author states that the maximum current density for obtaining an adherent copper deposit is higher the greater the concentration of the solution and the more completely local dilution is prevented by stirring. In the case of a normal solution of copper sulphate and sulphuric acid, a current of 2 amperes per square decimeter is not too great. No advantage results from measuring the loss of the anode to determine current.—*Zeitschr. Electrochem.*, iii, 479–482, 493–497, May, 1897. G. F. B.

4. *On the Commencement of the Combination of Hydrogen with Oxygen.*—An investigation has been made by BERTHELOT to determine the precise character of the influence which is exerted upon the combination of oxygen and hydrogen by the walls of the vessel containing the gaseous mixture. The two gases were always mixed in the proportion of two volumes of hydrogen and one of oxygen. It was noted that in presence of dry barium oxide, no combination took place at ordinary temperatures, nor even at 100° or 182°. At 250°, however, 77 per cent of the gaseous mixture disappeared in five hours, and at 280° the whole of it disappeared in 26 hours. At first, as subsequent experiments showed, the oxygen disappeared more rapidly than the hydrogen, a portion of it uniting with the barium oxide to form peroxide which the hydrogen afterward reduced. Thus, for example, at 280° all the oxygen disappeared after five hours, while 16 per cent of the hydrogen remained; the latter however being slowly absorbed. The action of the barium oxide appears analogous to that of platinum. A similar action was observed with potassium hydroxide, the gases combining slowly at 250° and quite rapidly at 280–300°. In this case the glass is attacked, the manganese which it contains forming alkali manganates. Here also the oxygen disappears more rapidly than the hydrogen, peroxides and manganate being formed. In presence of moisture glass was found to absorb considerable oxygen; but if the water be in larger proportion, no such absorption was observed. The author regards this intermediate formation of alkali peroxides as taking an important part in the combination of hydrogen and oxygen when heated in glass vessels.—*C. R.*, cxxv, 271–275, August, 1897.

G. F. B.

5. *On the Different Varieties of Carbon* (*Amorphous, Graphite, Diamond*).—An elaborate investigation has been made by MOISSAN upon the production, modes of occurrence and general properties of the various forms of carbon. The first of his three papers is devoted to amorphous carbon. Eleven different products were examined, made as follows: (1) by the imperfect combustion of petroleum, (2) by the imperfect combustion of acetylene, (3) by the detonation of acetylene with mercuric fulminate, (4), by the action of sulphuric acid on starch, (5) by the action of ferric chloride on anthracene at 180°, (6) by the decomposition of carbon tetriodide at 200°, (7) by the action of light on carbon tetriodide, (8) by the action of a Smithson couple on a solution of carbon protoiodide in carbon disulphide, (9) by the action of zinc filings on carbon tetriodide, (10) by the action of magnesium on a solution of the tetriodide and (11) by the action of boron at a red heat on carbon dioxide. All the specimens of carbon thus produced were amorphous and more or less impure, the complete purification in many cases being very difficult if not impossible, the carbon holding traces of moisture, hydrocarbons and the previously associated elements, iodine, lead, zinc, etc., with great avidity. The most impure samples were those given by methods

(4) and (5). By whatever method produced, the density of the amorphous carbon was always less than two, that of the purest non-ignited lampblack being 1·76. Amorphous carbon polymerizes on heating, thus raising its ignition point in oxygen and its resistance to chromic acid solution.

The second paper treats of graphite, the samples considered being from Ceylon, Borrowdale, Ticonderoga, Greenville, Omeansk, Mugrau, Scharzbach and Karsok; and also from an American pegmatite, and the Blue Earth from the Cape. The carbon in meteorites is considered, and also that separated from iron. The densities, the ignition-points and the rates of oxidation of artificially prepared samples are discussed and the displacement of carbon in fused cast-iron by boron and silicon is considered. The preparation and properties of intumescent graphite are also described.

In the third paper, the diamond is taken up, and its properties are given and the composition of the ash left on combustion. The occurrence of diamonds in the Blue Earth from the Cape, in sand from Brazil and in the Cañon Diablo meteorite is discussed; and then the author passes to consider the solubility of carbon in various metals at ordinary pressures, and the formation of definite carbides, as well as the effect of high temperatures on different forms and the properties of carbon vapor. Numerous experiments are described on the artificial production of diamonds and a description is given of the method used for the combustion of artificial diamonds.—*Ann. Chim. Phys.*, VII, viii, 289–305, 306–347, 466–558, July, Aug., 1897. G. F. B.

6. *Die Wissenschaftlichen Grundlagen der Analytischen Chemie.*; Elementar dargestellt von W. Ostwald. Zweite vermehrte Auflage, 12mo, pp. x, 200, Leipzig, 1897 (Engelmann), 5 marks.—This book, like all of Ostwald's writings, has been remarkably well received by chemists; so much so that a new edition has been called for in less than three years. It treats of the scientific basis of analytical chemistry in the light of the more modern views of physical chemistry of which its author is so distinguished an exponent. It is divided into two parts, the first being theoretical and the second practical. The subjects treated in the first part are the detection of substances, the separation of substances in the solid, liquid and gaseous states, physical separation-methods, chemical methods of separation, and the measurement of substances. The second part treats of the application of these principles to the detection and estimation of substances, the first chapter considering acids and bases, the second the alkali metals, and so on, ending up with chapters on the non-metals and on the calculation of analyses. The most important chapter in the book seems to us to be that on chemical separation methods, in which is considered the modern theory of solution, including Van't Hoff's theory of osmotic pressure and Arrhenius' theory of electrolytic dissociation, according to which "salts do not exist as such in aqueous solution but are more or

less completely split up into their constituents or ions." The substances detectible by reagents therefore are these free ions only. Thus the chlorine in metallic chlorides is an ion when in solution and hence reacts with silver nitrate; while chlorates, chlor-acetates and chloroform do not so react, since these substances contain no chlorine ions. The ions of potassium chlorate are K and ClO_3 and it is these ions which react with suitable reagents. In short all the reactions of analytical chemistry when they occur in solution are ionic reactions. Thus the author defines an acid to be a compound which contains hydrogen as an ion when in aqueous solution and a base to be one which under like circumstances contains the ion hydroxyl. The reading of such a book as this by the student cannot fail to be of the greatest advantage to him, since it leads him to consider the philosophy underlying his analytical processes and thus broadens out his horizon. The book is worthily dedicated to Wislicenus. G. F. B.

7. *Lehrbuch der Allgemeinen Chemie;* von Dr. WILH. OSTWALD, Professor an der Universität zu Leipzig. In zwei Bänden. Zweiten Bandes, zweiter Teil. *Verwandtschaftslehre.* Zweite Lieferung, Bogen 14–26. Zweite umgearbeitete Auflage. Leipzig, 1897 (W. Engelmann).—This is the part last issued of the remarkable Treatise on General Chemistry by Ostwald, now appearing in its second edition. It is not too much to say that it appears destined to exert upon the science of chemistry a more important influence than any other similar treatise now extant.

G. F. B.

8. *Inorganic Chemical Preparations;* by FRANK H. THORP, Ph.D., Instructor in Industrial Chemistry in the Mass. Inst. of Technology. 8vo, pp. iv, 238, Boston, 1896 (Ginn & Co.)—The author has sought in this manual to provide the student with such simple directions in manipulation and experimentation as shall enable him to prepare the 100 substances mentioned in it with accuracy and success. The matters it treats of are well considered and the book will no doubt serve a useful purpose in instruction. G. F. B.

9. *Experimental Physics;* by WILLIAM A. STONE, A.B., Instructor in Physics at the Phillips Exeter Academy, 12mo, pp. vi, 378. Boston, 1897 (Ginn & Co.)—An elementary laboratory manual for students in preparatory schools and academies. The subjects seem well selected, the descriptions accurate, the directions plain, the illustrations good, and the questions upon the work suggestive. G. F. B.

10. *Physical Experiments;* A Manual and Note Book. By ALFRED P. GAGE, Ph.D., 8vo, pp. ix, 97, Boston, 1897 (Ginn & Co.)—A laboratory note book containing, among other exercises, those required for admission to Harvard University. G. F. B.

11. *Transmission of Radiant Heat by Gases at Varying Pressures.*—CHARLES L. BRUSH shows that Dulong and Petit's sixth law: "The cooling power of a fluid diminishes in a geometrical progression when its tension itself diminishes in a geometrical pro-

gression. If the ratio of this second progression is 2, the ratio of the first for air is 1·366; 1·301 for hydrogen; 1·431 for carbonic acid; and 1·415 for olefiant gas," is only approximately true in the case of a large balloon and at pressures from a few millimeters upward. It is not true when a small balloon is used, and at small pressures it is not true of large or small balloons. In small balloons the cooling effect of the last millimeter of air is nearly ten times as great as that of all the rest up to atmospheric pressure combined."

The author finds that Professor Crookes's statement: "That each additional diminution of a millionth would produce a still greater retardation of cooling, so that in such high vacuo as exist in planetary space the loss of heat—which in that case would only take place by radiation—would be exceedingly slow," is not true, for the curves representing the rate of cooling do not break down materially at pressures as low as a twentieth of a millionth. The enormous heat-conducting capacity of gases at very small pressures is shown by the curves. In the large bulb used, hydrogen at a pressure of only twenty-six millionths of an atmosphere transmits heat as rapidly as the ether. At seventy-six millionths it equals air at atmospheric pressure, that is to say it does the work of nearly two hundred thousand times its weight of air.—*Phil. Mag.*, Jan., 1898, pp. 31–42. J. T.

12. *Conductivity of Carbon for Heat and Electricity.*—L. CELLIER has determined the heat and electrical conductivity of carbon and finds that Professor Weber's law connecting heat conductivity and electrical conductivity does not hold in the case of carbon, and that carbon cannot be at all compared with metals.—*Wied. Ann.*, No. 7, 1897. J. T.

13. *Determination of Relative Heat Conductivity by the Isothermal Method.*—W. VOIGT describes a modification of Senarmont's method of determining relative conductivity by means of the melting of a substance on the surface of the bodies. Voigt uses a mixture of wax and turpentine, with *Elaidinsäure* in definite proportions, and obtains melting curves of extraordinary sharpness. Double plates were employed, cut in the form of right-angled triangles, with acute angles of 45°. These plates were put together so as to form a right-angled parallelogram, and having been cooled with the above substances were exposed to a source of heat, and the angles between the melting curves on the two plates were measured. The correspondance between the observed and calculated values was very good.—*Wied. Ann.*, No. 1, 1898, pp. 95–100. J. T.

14. *Röntgen's Original Papers on the Röntgen Rays.*—The original papers of RÖNTGEN, first published in the proceedings of Der Würzburger Physik. Medic. Gessellsch., have been republished in the current number of Wiedemann's Annalen der Physik and Chemie, as leading articles. There is a quiet irony in this, as if to show that Röntgen had anticipated the labors of the army of investigators who have endeavored to extend his work.—*Wied. Ann.*, No. 1, pp. 1–37. J. T.

15. *Johanniskäfer Light.*—In an earlier paper, H. MURUOKA stated that the light from this species of fire insect, when filtered through paper or cardboard, could affect photographic plates. In connection with M. Kasuya the author has re-examined the phenomenon and finds that it was due to a moisture in the cardboard which brought out a peculiar property of the latter. This moisture was communicated doubtless by the fire insects. Aqueous vapor alone did not produce photographic effects. When bits of the cardboard, however, were placed in water, a photographic plate exposed to the vapor of water was sensibly blackened. Various organic substances were then tried, and photographic effects were produced by a large range of such substances, among which were resin, coffee, camphor, tea, also oil of turpentine, mercury and alcohol. It was found that zinc, cadmium and magnesium act upon photographic plates, and it was noteworthy that cadmium and magnesium blacken photographic plates only around the boundaries of the pieces of metal. Cadmium oxide exhibited an effect which cannot be ascribed to radiation or to vaporization. For instance, two thick pieces of cardboard A and B of the size of the to-be-covered photographic plate were perforated—A with a little square hole, B with a large one, both in the middle of the plates. A was laid upon a glass plate and the perforation was filled with oxide of cadmium powder. B was then laid on A and on B was placed a photographic plate. It was expected that the blackening would extend over the entire surface of the perforation in B, for the vapor of the powder could reach all points of this perforation. The darkening, however, was confined to a surface equal to the little square opening.

If A and B were placed 1^{cm} apart and a copper rod was placed between the openings without resting on either cardboard, there was no blackening under the copper rod. This seemed like a phenomenon of radiation, but radiation apparently cannot explain the limitation of the blackening in the first case.— *Wied. Ann.*, No. 1, 1898, pp. 186–191. J. T.

16. *On the Occlusion of Hydrogen and Oxygen by Palladium;* by LUDWIG MOND, WILLIAM RAMSAY, and JOHN SHIELDS. (Abstract of a paper read December 16, 1897, before the Royal Society.)—During their investigations on the nature of the occlusion of gases by finely divided metals, and in particular on the occlusion of hydrogen and oxygen by platinum black, the authors have had occasion to examine the behavior of palladium to these gases.

The palladium was employed in three states of aggregation, viz: in the form of (*a*) black, (*b*) sponge, and (*c*) foil. Palladium black, prepared in the same way as platinum black, contains 1·65 per cent of oxygen, or, taking the density of palladium black as 12·0, 138 volumes of oxygen. It differs from platinum black, however, inasmuch as the oxygen cannot be removed in vacuo at a dull red heat, and consequently had to be determined in the ignited substance by passing hydrogen over it and weighing the

water produced. Palladium black dried at 100° contains 0·72 per cent of water, and hence, on the assumption that the oxygen exists as PdO, we have for the analysis of palladium black—

Pd	86·59 per cent	
PdO	12·69 "	= 1·65 per cent O_2
H_2O	0·72 "	

On heating in an atmosphere of oxygen, palladium black goes on absorbing oxygen at least up to a read heat, with the formation of a brownish-black substance, which does not again lose its oxygen at a dull red heat in vacuo. The amount of oxygen absorbed (nearly 1000 volumes) was about one and a half times as much as corresponds with the formula Pd_2O, and if the ignition had been sufficiently prolonged, the whole of the palladium would probably have been converted into the oxide PdO.

Palladium black, when exposed to hydrogen gas, absorbed over 1100 volumes, but of this only 873 volumes were really occluded, the remainder having formed water with 139 volumes of oxygen originally contained in the black, which is in good agreement with the direct gravimetric estimation.

Of the hydrogen occluded, about 92 per cent was pumped off slowly at the ordinary temperature, and almost the whole of the remainder at 444°. Increase of pressure of the hydrogen from one atmosphere up to 4·6 atmospheres had no influence on the quantity occluded at the ordinary temperature.

The pure palladium sponge remaining in the experimental tube after the above experiment was over occluded 852 volumes of hydrogen, and about 98 per cent of this was extracted in vacuo at the ordinary temperature.

New palladium foil behaved in a very peculiar fashion. At first it scarcely occluded any hydrogen even after ignition in the gas and subsequently cooling down. It was therefore charged and discharged several times electrolytically with hydrogen, but still it persistently refused to occlude any appreciable quantity when replaced in an atmosphere of hydrogen.

After powerful ignition in the blowpipe flame, when it was probably oxidized and then again reduced at a still higher temperature, it was introduced once more into the experimental tube. It immediately occluded a considerable quantity of hydrogen, and by maintaining the temperature between 100° and 130°, a large additional quantity was slowly absorbed. On cooling down to the ordinary temperature, hydrogen was again occluded, and it was finally found to have taken up 846 volumes, i. e. approximately the same quantity as the black or sponge.

The hydrogen occluded by palladium foil is given off again very slowly at the ordinary temperature in vacuo, but rapidly and almost completely at 100°.

The paper contains some attempts to explain the extraordinary behavior of palladium foil.

The heat evolved on the occlusion of hydrogen by palladium black was measured in an ice calorimeter (temperature of the room 20–24°) in nearly the same way as the corresponding heat of occlusion of hydrogen by platinum black, thereby avoiding errors due to the preëxistence of oxygen in the substance.

Favre's statement that the heat of occlusion remains constant for the different fractions of hydrogen occluded was confirmed, and it was found that +46·4 K (4640 g. cal.) were evolved per gram of hydrogen occluded.

The authors consider that this number may be taken as correct within 1 per cent, and compare it with the different values found by Favre and those calculated by Moutier and Dewar.

If the external work done by the atmosphere be eliminated, the heat evolved per gram of hydrogen occluded becomes +43·7 K.

The heat evolved per gram of oxygen absorbed was also determined in an indirect manner, and found to be +11·2 K (1120 g. cal.).

This number, referred to 16 grams of oxygen, lies intermediate between the values given by Thomsen for the heat of formation of palladious and palladic hydroxides, and may be consistent, considering the accuracy of such measurements, with the formation of either of these hydroxides or with a mixture of both. In any case it is of the same order of magnitude, and taken in conjunction with the behavior of palladium black when heated in an atmosphere of oxygen, is undoubtedly in harmony with the view that the absorption of oxygen by palladium black (and probably also by platinum black) is a true phenomenon of oxidation.

The authors have also investigated the atomic ratio—palladium : hydrogen for fully charged palladium black, sponge, and foil, and give in tabular form the corresponding ratios deduced from experiments by Graham and Dewar in which wire and block palladium were charged with hydrogen electrolytically. They have arrived at the conclusion that no matter whether the palladium exists as black, sponge, foil, wire, or compact metal, or whether it is charged by direct exposure to hydrogen gas (the proper conditions being observed), or charged electrolytically, the amount of hydrogen occluded in each case is approximately the same, the atomic ratio varying between 1·37 and 1·47.

Hoitsema has shown that Troost and Hautefeuille's deduction that a compound exists having the formula Pd_2H is not warranted. The constancy of the heat of occlusion over the whole range of absorption is also opposed to the view that such a compound is formed.

The composition of fully charged palladium hydrogen corresponds closely with the formula Pd_3H_2 first suggested by Dewar. The principal and almost only evidence, up to the present, in favor of the formation of such a definite chemical compound is to be found in the approximation of the above atomic ratios to the

theoretical value 1·5, required by the formula Pd_2H_2. Although Hoitsema's arguments may be equally well directed against the existence of this compound, the authors consider that additional and independent evidence is desirable, and hope to be able to provide it.

It is also shown that the heats of occlusion of hydrogen in platinum and palladium black are not in favor of the view which has sometimes been put forward, that the heat of occlusion of a gas represents the heat of condensation or liquefaction of the gas in the capillary pores of the absorbing substance, or the heat of solidification or fusion.

17. *Refractivities of Air, Oxygen, Nitrogen, Argon, Hydrogen and Helium.*—The results obtained by RAMSEY and TRAVERS in an investigation of the refractivities of a series of gases are given in the following table:

Refractivities of Gases, Air equal to Unity.

	Directly compared.	Through			
		Oxygen.	Nitrogen.	Hydrogen.	Argon.
Hydrogen	0·4733	0·4737	0·4727	....	....
Oxygen	0·9243	....	0·9247	0·9237	0·9261
Nitrogen	1·0163	0·0155	....	1·0170	1·0191
Argon	0·9596	0·9577	0·9572	....	....
Carbon dioxide	....	1·5316	....	....	....

The values are compared here directly and also through the other gases mentioned. The greatest care was taken to obtain pure material in each case. The special method of experiment is stated to have been the same as that described by Lord Rayleigh (Proc. Roy. Soc., lix, 203):

The authors have also calculated the refractive index of air from the determinations obtained with the individual gases present, viz.

Oxygen	0·9243
Nitrogen	1·0163
Argon	0·9596

and the densities of the constituent gases, and obtained the following numbers:

$$(1·0163 \times 78·15) + (0·9243 \times 20·91) + (0·9596 \times 0·94) = 99·653$$

They hence conclude that the refractivity of the mixture, air, is somewhat less than that of the sum of the refractivities of its constituents taken in the proportion in which they occur. This discrepancy is not sensibly altered by such minor changes in the data given as seem to be admissible.

To test the same point similar calculations were made with a mixture of hydrogen and helium, selected as being particularly favorable since their critical points are so low and they hence approximate closely to the ideal gas. The result was to obtain a

value of the refractivity of the mixture which was about 3 per cent *higher* than the observed value, the difference being of an inverse character to that of a mixture of oxygen and nitrogen, as was to have been anticipated.

A third experiment made with "artificial air" consisting of a mixture of 19·13 per cent carbon dioxide and 19·29 per cent of oxygen, gave a result which was less than that calculated. The difference was not great, but was believed to considerably exceed the error of the several determinations.

In regard to the theoretical point involved, the authors make the following remarks:

"The coefficient of compressibility of hydrogen is too small, while that of other gases, such as oxygen and nitrogen, is too great. The effect of mixing equal volumes of hydrogen and helium, each of which has too large a coefficient of elasticity, is to cause each to occupy twice the volume that they previously occupied, and to halve approximately the pressure for each. The pressure is therefore lower than it would be for an absolutely ideal gas, for each gas, hydrogen and helium. The sum of these pressures will accordingly be too low, or transposing, the sum of the volumes will be too great. The opposite argument holds for air.

Now, in considering volumes we deal not merely with the co-volume, i. e., the space occupied by the molecules, but also with the interstitial space inhabited by the molecules. But the refractive power, if Clausius's deduction from the formula of Lorentz and Lorentz is correct, is a function of the dielectric constant, and hence of the co-volumes of the gases. And here the discrepancy is more easily detected than by any determination of density. It must therefore be concluded that gases are not, as postulated by Dalton, indifferent to one another's presence, but that they modify one another's properties in the same manner as do liquids, though to a different extent. This mutual action at high pressures and small volumes modifies even the volume relations, as recently shown by Dr. Kuenen. And it must persist at low pressures and large volumes, though it may not always be possible to make measurements of pressure and volume accurate enough to lead to its detection. The refractivity, however, seems to be a means delicate enough to be used for this purpose."—*Proc. Roy. Soc.*, lxii, 225.

18. *Experiments with some Electro-Chemical Actinometers.*—M. H. Rigollot has recently published in the Annales de l'Université de Lyon the results of an interesting series of experiments, having as their object the investigation of the electromotive force developed by the action of light upon one of two metallic plates immersed in an electrolyte; the other being kept in darkness. The experiments were carried on with plates of copper, covered respectively with the oxide, fluoride, chloride, bromide, iodide; also with plates of tin having a surface of oxide, and of sulphide, and finally of silver sulphide. The investigation

includes the effect of white light in general, then that of different portions of the spectrum on the plates specified, and finally the effect of sensitizing the plates with various coloring matters. As sources of illumination, gas, the electric arc, and solar light were employed, the two last exclusively where the spectrum was needed. The special arrangement of the apparatus is described in detail, and then the results obtained with each of the substances under examination, for the three cases mentioned. In the cases when the spectrum was employed, a series of plotted curves show the variation of the electromotive force for waves of different length and particularly the point at which the maximum was reached. As coloring matters, various substances were employed; thus with plates of copper oxidized, eosine, safranine, erythrosine, etc., were used. These had a remarkable effect in changing the position of the maximum in the spectrum.

As an example of the results obtained the following table is quoted: it gives the electromotive force (E.M.F.) developed with plates of copper oxidized, the effect varying widely with the degree of oxidation.

Degree of oxidation.	E.M.F. developed.
Straw-yellow	5×10^{-5} volt.
First violet	7
Second "	118
Third "	194
Oxid. more advanced	194
Blackish	7

The author concludes that by employing the substances mentioned, actinometers highly sensitive to light can be formed, the electromotive force of which, other conditions being equal, depends upon the electrolyte used. The maximum of sensibility in the spectrum for a given wave-length depends on the nature of the sensitive layer, and is independent of the electrolyte. The use of the coloring matters employed serves to increase the electromotive force for radiation, but gives a maximum for a certain wave-length dependent upon the choice of the material. This maximum always takes place for waves of greater length than those which correspond for the maximum absorption of light by the same coloring matter.

In discussing various applications of such actinometers, the author gives, for example, the actinic degree, defined as $\frac{e_2}{e_1}$, for various forms of light, including gas, Drummond light, the magnesium lamp, and the electric arc. Here e_1 is the deviation of the luminous point when a Carcel lamp illuminates the actinometer, and e_2 the same when the various light sources mentioned below are employed. The results are as follows:

	e_2	e_1	Actinic degree. $\frac{e_2}{e_1}$
Gas burner	39	39	1·0
Auer " No. 0.....	42	"	1·08
" " No. 1.....	43	"	1·10
" " No. 2.....	43·5	"	1·12
Drummond light	48	40	1·20
" "	60	"	1·50
" "	60	"	1·50
Magnesium "	107	39	2·72
Electric arc., 8 amp.	106	40	2·70
" 15	120	39	3·08
" 17	125	"	3·2
" 18	130	"	3·3

II. Geology and Natural History.

1. *Earth Movement;* by Charles R. Van Hise, Trans. Wisconsin Acad. Sci., Art, and Letters, vol. xi, pp. 465–516, Jan., 1898.—The "gravitation theory" suggested by Prevost in 1840 is presented in this paper with great force and clearness in the light of the science of to-day as the explanation of the various phenomena of earth movement. Epeirogenetic, orogenic and epigene movements are all alike shown to be gravitative. Vulcanism, too, is referred to the same cause. The dominant force which is behind the great regional extrusions of igneous material is gravity. Further it has been noted that these extrusions are contemporaneous with great crustal movements. The phenomena may be considered under the headings of, vulcanism in connection with regional compressive movements, vulcanism in connection with regional tensile movements, and local vulcanism" (p. 497). "I would not underestimate the power of steam in vulcanism, but that its expansive power is the chief force in the transfers of liquid material within the earth seems to me to be wholly unproved. The dominating force as explained is believed to be that of gravity" (p. 502).

The author explains the deep-seated flowage of material from the oceanic basins landward in continental growth as follows:

"It has been supposed that the regions below the sea have a higher conductivity than the continents and their downward extensions. If this be so, the former regions would ever continue to cool more rapidly than the latter, and would contract more. Both of these contractions would result in concentration of the rocks of the sea bed and in bringing them nearer to the center of the earth than the continental masses. Hence gravity would be more effective on the mass below the sea than elsewhere, and differential stresses would result. The quantitative value of the increased effectiveness of gravity on the mass of the sea beds should be estimated upon various numerical suppositions, but the

amount of contraction in cooling, solidification, and crystallization is so great that it can hardly be doubted that its effectiveness would be considerably increased. As a result of the unequal contraction the continental ship would be no longer in isostatic equilibrium. Differential vertical movement would be set up, and material below the sea areas would tend to flow toward the land areas, and thus tend to elevate the continents, but the average of the movements would be downward. Whether the continents absolutely or relatively rise under these stresses would depend upon the average amount of contraction of the earth. It is probable that this contraction would more than counteract the tendency to uplift, and therefore that relative elevation, and not absolute elevation would occur. The process above outlined might continue until approximate isostatic equilibrium has again been reached. We thus have a real cause for a very long continued growth. When the hypogene forces causing more rapid subsidence of the sea beds than of the continents, and consequently relative upheaval of the continental masses, shall have finally exhausted themselves, it cannot be doubted that the epigene forces will win, and that the continental masses will be reduced to an even platform slightly below the level of the sea.

. . . . Summarizing, we have seen that differential subsidence slowly but surely causes the continental masses to rise or fall with reference to the surface of the sea. As a result of the subsidence of great areas, smaller areas, such as the plateaus and mountain ranges and systems, may be elevated. The horizontal stresses, thickening the strata along the zones of plication and producing the mountain systems and plateaus, are but incident to the larger movements of subsidence. By vulcanism vast masses of magma are introduced into the outer part of the crust of the earth, or spread over its surface. The continental areas, wherever they are above the sea, are being degraded by the wasting forces of water, ice, and wind. Concurrent with these movements is deep-seated flowage. As a result of these movements it is possible that the continents may grow. The remote cause to which continent-making, differential subsidence, mountain-making and attendant phenomena, epigene transfer, vulcanism, and deep-seated compensatory flow, are due, is the force of gravity persistently working upon a plastic contracting mass: and therefore the center of gravity of the various masses moved, is nearer the center of the earth as a result of the movements." H. S. W.

2. *The Geology of Massanutten Mountain in Virginia;* by ARTHUR COE SPENCER, pp. 1–54, 1 map and 3 diagrams, 1896. (A thesis for degree of doctor of philosophy, Johns Hopkins University.)—The selection of an isolated synclinal area such as the Massanutten Mountain for careful study has resulted, as might be expected, in the testing of a large number of speculations regarding mountain-building and the formation of the original series of sediments. The present study was suggested and guided by Mr. Bailey Willis, whose extended studies of the Appalachians well fit him to

propose nuts to crack, and it is not unexpected to find very little new light thrown upon these problems by one entering upon their study for the first time, nevertheless Mr. Spencer has given a very vivid analysis of the facts in the case. The stratigraphy, structure, topography and geological history are each wrought out with distinctness and fullness. The chapter on structure is particularly interesting, showing the secondary folding of the beds in the course of the principal synclinorium, and calling attention to the still finer puckerings and the cleavage planes developed in the finer sediments, illustrating the high degree of complexity of movements suffered by the rocks of a much plicated region. The author has attempted to give, in detail, the hypothetical conditions of the region for each period of change in deposition. This part of the paper, it seems to the writer, is less satisfactory and chiefly because of the need of an immense body of facts before any satisfactory solution of such problems is possible.

H. S. W.

3. *Geological Survey of Canada.* G. M. DAWSON, Director.—The following part of the Annual Report, vol. ix, for 1896 has been received, viz:

Part S. Mineral Statistics and Mines (No. 625). ELFRIC DUER INGALL and Assistants, pp. 15–172*s*, 1897. The following interesting facts regarding the mineral production and its rate of increase is given in the introduction. In 1886 the value of the mineral production of Canada is estimated at a little over ten million dollars. The production had increased in 1896 to over twenty-two and a half million dollars, or 125 per cent. In comparison with the value of production in the United States, Canada's production in 1896 amounts to 3½ per cent of that of the United States for the same year. The relative per capita production of minerals for the two countries is as follows, viz: for Canada about $4.50 and for the United States about $8.00. H. S. W.

4. *Geological sections from Moscow to Siberia and return;* by PERSIFOR FRAZER, Ex. Proc. Acad. Nat. Sci., Phil., October, 1897, pp. 405–457.—The author has given in this paper a summary account of the Oural excursion of the last Congress of Geologists, adding to the particulars given in the carefully prepared (in French) *libret guides* of the excursions, account of his own experiences and views. H. S. W.

5. *Note on the "Florencia Formation";* by HENRY A. PILSBRY. (Communicated.)—Upon reading the valuable paper by Mr. O. H. Hershey upon the "Florencia Formation," in the August number of this Journal, my attention was particularly directed to the position assigned to the formation, in the Pleistocene series, *below* the Iowan loess. It seems to me possible that this one point requires further investigation either to establish or disprove the conclusion reached by Mr. Hershey, as the result evidently of much careful observation.

The principal reason for doubting the assigned age of the Florencia deposit is that its fauna is apparently much more

modern than that of the Iowan loess. The list of Florencia fossils consists exclusively of species still living in the same region. Every one is doubtless to be found to-day in the flood débris of any creek of moderate size in northwestern Illinois.

On the other hand, the Iowan loess, as developed at such a typical locality as Iowa City, Iowa, for example, contains an assemblage of species nowhere occurring recent, including some species and varieties now extinct. For comparison with Mr. Hershey's Florencia list of fossils, the following characteristic Iowan loess forms may be mentioned:

Zonitoides shimeki Pils.
Conulus fulvus Drap.
Pyramidula strigosa iowensis Pils.
Pyramidula striatella Anth.
Pupa muscorum L.
" *blandi* Morse.
Sphyradium simplex Gld. (variety).
Polygyra multilineata Say.
Helicina occulta Say.
Succinea avara Say (variety).
" *lineata* W.G.B. "
" between *lineata* and *obliqua*.
Limnæa humilis Say.
" *desidiosa* (?).

Many others might be enumerated; but it will be observed that in this brief list of the forms found abundantly at Iowa City, *Zonitoides shimeki* and the strongly marked variety of *Pyramidula strigosa* are extinct; the Succineas, while probably referable to recent species, are still very unlike the living shells; the *Helicina* is approaching extinction, being now excessively local and discontinuous in distribution, while several other species do not now occur in the Iowa or Illinois fauna.

These considerations render it very likely that the Iowan loess fauna is an older one than that of the Florencia formation; for it is inconceivable that we should have sandwiched between the modern fauna and a prior one in all respects identical with it, a fauna containing extinct species and recognizably differentiated varieties, such as that of the loess.

It seems likely therefore that the Florencia is a very recent formation in comparison with the Iowan loess.

The discrepancy observed by Mr. Hershey between his list of Florencia fossils and the published lists of Iowan loess fossils is, so far as generic differences are concerned, merely a matter of nomenclature; the loess lists giving the older generic names, while Mr. Hershey's Florencia list is expressed in the modern generic arrangement. There is therefore no such wide faunal divergence between the two deposits as would appear from Mr. Hershey's remark.

Academy of Natural Sciences, Philadelphia.

6. *Geology of Franz Joseph Land.*—A recent number (Dec. 15) of the Quarterly Journal of the Geological Society contains an interesting article by E. T. Newton and J. J. H. Teall, descriptive of rocks and fossils from Franz Joseph Land, collected by the Jackson-Harmsworth Expedition. The general results arrived at, which throw much light upon the hitherto almost unknown

geology of this region in the far north, are given in the following paragraphs.

"In conclusion, we may perhaps be allowed to sketch out briefly the salient features in the geological history of Franz Josef Land, so far as this can be done in the light of our present knowledge. Passing over the plant-bed at Cape Stephen, the age of which is uncertain, the first event of which we have any record is the deposition of a series of shales and sandstones containing plant-remains, beds of lignite, and other evidences of littoral or estuarine conditions. Intimately associated with these shallow-water deposits are some purely marine beds, the age of which is placed beyond all doubt by the occurrence of such well-characterized zonal fossils as *Ammonites macrocephalus* and *A. modiolaris*.

Owing mainly to the brilliant researches of Neumayr, it is now generally recognized that the Jurassic sea reached its greatest extension in the present land-areas during the Callovian and Oxfordian periods. Hydrocratic and geocratic movements alternated during Jurassic times, with a decided balance in favour of the former, and a recession of the coast-line towards the north. Even in the North of Scotland we find no decided evidence of the proximity of land during the Oxfordian period, although the lower portions of the Jurassic formation are represented by littoral and estuarine deposits.

Under these circumstances the discovery of *A. macrocephalus*-beds in Franz Josef Land in association with plant-bearing strata is of special interest. It extends the range of this ammonite several degrees towards the north, and shows, in all probability, that during the period of its existence a coast-line lay somewhere in this direction. Marine deposits of Callovian and Oxfordian age are now known to range from Sutherland to Cutch and from Franz Josef Land to the North of Africa; and *A. macrocephalus* is one of the most widely distributed of all Jurassic ammonites. The soft Jurassic sediments were subsequently covered up and preserved from destruction by vast flows of basaltic lava; and it is not a little remarkable that rocks of the same general period have been preserved in the same way in districts so far removed from Franz Josef Land as the Northwest of Scotland and Abyssinia. We have already pointed out that Dr. Nansen refers the basalt in part to the Jurassic period; but in view of the fact that the basalts of the West of Scotland were at one time supposed to be of the same age, for reasons similar to those relied upon by him, this conclusion cannot be regarded as definitly established. At the same time it is important to notice that, if we except the North of Ireland, the Upper Cretaceous period is unrepresented, or but feebly represented, by sedimentary deposits in regions like the Deccan of India and the high plateaux of Abyssinia, where basalts are extensively developed. It is therefore quite possible that the vast outpourings of basic lavas which have given a special character to extensive areas of the earth's surface may have commenced in pre-Tertiary times.

The present configuration of the archipelago of Franz Josef Land conclusively proves that it is formed of the fragments of an old plateau. The land frequently ends off in high cliffs, capped with sheets of basalt which must have extended far beyond their present limits. When one compares the topography of this district with that of the Fæöes and the West of Scotland, one is inclined, notwithstanding the immense tracts of water which now separate these localities, to ask whether they may not at one time have been continuous, and whether the northern portion of the North Atlantic, as suggested by Suess, may not be of comparatively recent origin.

But whatever answer may be given to this question, it is clear that at the close of the volcanic period the various islands of Franz Josef Land were united and formed part of an extensive tract of land. This land was subsequently broken up, partly, in all probability, by the sinking of certain areas along lines of fault, and partly by denudation.

The final stages in the history of the district are represented by the raised beaches, which prove that this region, like so many other portions of the extreme north, has quite recently been under the influence of a geocratic movement."

7. *On a remarkable occurrence of xenotime;* by G. CHRISTIAN HOFFMANN. (Communicated.)—A mineral not previously identified as occurring in Canada, has somewhat recently been observed in the township of Calvin, province of Ontario. Here, in one part of a coarse granite vein—composed of quartz, microcline, albite or oligoclase, muscovite and biotite, Mr. C. W. Willimott found, embedded in the microcline, a mass weighing not less than 312 grams which on examination by Mr. R. A. A. Johnston proved to be xenotime. The mass is made up of a closely compacted aggregation of more or less divergent long slender prisms, among which, however, a few stout individuals are observable, one of which measures 7^{mm} in diameter. It has a prismatic cleavage; an uneven fracture; a dark reddish-brown color; a resinous luster, and a light flesh-red streak. The hardness is about 5, and the specific gravity, at 15·5° C., 4·395. Small quantities of an altered magnetite and very small crystals of a reddish-brown garnet, most probably spessartite, are found accompanying the mineral; and a fine specimen of a yellow beryl has been received which was also said to have come from this vein.

8. *On the Crystalline Structure of Gold and Platinum Nuggets and Gold Ingots.*—A paper by Professor A. LIVERSIDGE, in the Proceedings of the Royal Society of New South Wales, gives the results of an investigation of a series of nuggets of gold and platinum and also of gold ingots. Sections of these were prepared and etched by means of chlorine water as well as investigated in other ways. A series of sixteen excellent plates show the effects of the action, and the main conclusions are stated as follows:

"As far as it [the investigation] goes, it proves that gold nug-

gets do not show that they have been built up of concentric coatings round a nucleus, but that they possess a well marked internal crystalline structure and that they usually enclose foreign substances, also that a similar crystalline structure is shown by gold which has been fused; I do not, however, think that native gold has necessarily been in a fused condition, on the contrary I think it has been deposited from solution and usually within veins or pockets in rocks, although if it had been deposited round nuclei, it might still have possessed the crystalline structure which has been described and figured in this paper."

9. *Flora of Franz Josef Archipelago;* by HARRY FISHER.—In the Geographical Journal for December, 1896, pp. 560–563, I made some remarks on the above. Since the publication of that account I have had opportunities of studying this flora, and of comparing the results with those of almost every other known arctic region. A full account will shortly be presented to the Linnean Society. Mr. Armitage has told you that southwesterly winds are almost unknown in Franz Josef Land. I believe this will account, to some extent, for the flora being more scanty and stunted on the whole than that of almost all the other arctic regions. The summer temperatures are lower than elsewhere. There is no doubt that the presence of the Gulf Stream on the west and northwest coasts of Spitsbergen will account for the luxuriance of the flora up to Brandewjne bay, whereas the east coast of North-East Land resembles Franz Josef Land. The Gulf Stream, however, will not account for the comparative richness of the flora of Melville Island, of Grinnell Land, and of Port Foulke, the last named being on the Greenland side of Smith Sound; these are separated by channels of inconsiderable width from the mainland. To the north of Port Foulke is the Great Humboldt glacier, which has been considered to form a barrier to the northward progress of the flora on the west side of Greenland. We know next to nothing of the plant-life on the lands to the north of Peary Channel; but I expect an extension of the Grinnell Land flora will be found there, and probably an arctic Siberian type also. The most northern land in Asia, Cape Chelyuskin, has a smaller flora even than Franz Josef Archipelago (and most of the plants are as dwarf), notwithstanding that it is on the mainland of a vast continent. This can only be accounted for by supposing it to have been submerged until comparatively recent times; but the flora of arctic Siberia is generally poor in species.

There is one zoological fact of interest to the botanist. Young snowy owls visit Franz Josef Archipelago every summer; two of these handsome birds were killed on Cape Flora, and I found pellets and feathers of this species on all the capes which we visited. Several birds were seen besides the two which we killed. Does not their presence indicate the existence of the lemming, and therefore the willow, in recent times?

It is difficult to understand why some of the plants maintain an existence under such unfavorable conditions as the present,

unless they are, as they appear to be, dying-out remnants of a typical arctic flora. I am thinking of the starved colony of *Graphephorum Fisheri* Asa Gray (a grass), composed of about twenty lifeless-looking individuals on Mabel Island, and not seen elsewhere; and also of *Stellaria longipes* and Goldie, which presents a similarly lifeless appearance. Of this two flowers only were seen; they were on Cape Neale. Even flower-buds were not found elsewhere. The bald-leaved *Cerastium* makes no attempt at flowering. A few other plants merely exist. Unless the conditions improve, most of these plants will disappear; not, as in warmer climes, to be replaced by others, I fear, there being already abundance of spare ground untenanted by any plant. It is very remarkable that I should have found seedlings of the poppy (*P. nudicaule* L.), the scurvy grass (*Cochlearia fenestrata* Br.), and *Draba leptopetala* Fr. This was quite unexpected, for I know of nothing of the kind from similar latitudes. The anthers and stigmas of the poppy, so far as I had time for observation, were ripe at the same time. There are no insects which are likely to have assisted in fertilization in this case; but, as regards the scurvy grass, my observations lead me to the conclusion that diptera may occasionally assist, but at the same time they are more certainly foes than friends, inasmuch as their larvæ feed ravenously on the floral organs of this species. Seedlings of the scurvy grass were found on Gully rocks and on Cape Flora, sparingly. Those of the poppy were seen in one place on the latter cape. Seedlings of the *Draba* were found on Cape Flora, but in such limited quantity that they only occupied half a square inch. I look upon this last rather as an accidental result. The case of the poppy is a little stronger, and *Cochlearia* (scurvy grass) probably increases to some extent by seed in most summers. All attempts at solving the problem of the derivation of this flora are purely theoretical. The depth of the sea between Novaya Zemlia, Spitsbergen, and Franz Josef Archipelago only throws a little light on the subject. Geology and ocean currents render little service; possibly the working out of the driftwoods may throw some light on this obscure subject.

A large number of specimens of driftwoods were collected, and have been entrusted to Prof. Carr, M.A., F.G.S., F.L.S., of the University College, Nottingham, for examination. Of all of these numerous microscopical sections have been made, which will be compared with similar sections of known woods from Siberia, arctic Europe, and North America (prepared from specimens kindly supplied by the director of Kew gardens, supplemented by some in the Fisher collection in Nottingham Natural History Museum from the Russian Empire, all of which are authenticated by Dr. Regel and Herder). These driftwoods are mainly coniferous, but a few are non-coniferous, and it is hoped that the exhaustive examination to which they will be subjected will prove their identity and probable place of origin. The labor of collecting and sledging these woods, many of which were huge trunks,

was borne by Messrs. Jackson and Armitage and Dr. Koettlitz; some few were collected by Mr. Child and myself, my own task being a light one, consisting of cutting suitable pieces for examination and for specimens, etc., chiefly from the heaps which three of us made on Capes Gertrude and Flora. On Cape Mary Harmsworth Dr. Koettlitz collected woods, and Mr. E. Else brought a fine piece also. These are now in Prof. Carr's hands. A fine section was made on ("Tween") Cook's rocks by Mr. Child; this is with the others.

There are certain plants in Franz Josef Archipelago which give a color to the landscape, occurring as they do in patches or carpets up to an altitude of 500 feet. The poppy is the most showy, but several mosses rival this flower in brilliancy. I have previously mentioned in this Journal the bright color of these plants, but I did not specify them. There are four species which I ought to particularize: *Splachnum Wormskiöldii* Hornem., brilliant green; *Aulacomnium turgidum* Schwgr., pale yellow-green; *Bryum obtusifolium* Lindb., red to crimson and purple; *Orthothecium chryseum* Lorenz, golden yellow. It is interesting to find that these mosses flourish in the neighborhood of loomeries, and that in their absence they become quite scarce. This is particularly the case as regards *Splachnum*. "The Splachnum family are remarkable among mosses for the preference they exhibit for growing in bogs, on the droppings of animals such as sheep, cattle, or foxes, sometimes occurring also on the bones of dead animals."—*Geographical Journal*, February, 1898.

III. Miscellaneous Scientific Intelligence.

1. *International Congress of Zoology, 1898.*— The Fourth Congress of Zoologists is to be held at Cambridge, England, on the 23d of August, 1898. Sir John Lubbock has been appointed President, in the place of Sir W. Flower, who was elected to this position at Leyden, but was compelled to resign in consequence of ill-health. The Secretaries are F. Jeffrey Bell (3 Hanover Square, London, W.), G. C. Bourne and A. Sedgwick.

Circulars have been widely distributed making preliminary announcements in regard to the meeting and extending to British, Foreign and Colonial zoologists an invitation to be present. For the benefit, particularly, of those who may have failed to receive these documents, the following paragraphs are quoted from the circular issued by the Reception Committee:

"The seat of an ancient University, which counts among its *alumni* distinguished Zoologists, from the days of Ray and Willughby to those of Charles Darwin and Francis Balfour, seems to offer a peculiarly fit meeting-place for the Congress on its first visit to the British Islands, and the Reception Committee, including the present representatives of Zoological Science in Cambridge, hereby offer a cordial welcome to their brethren at home and abroad who may accept this invitation.

The Reception Committee hope to avail themselves largely of the facilities offered by the several Colleges of Cambridge for the accommodation and enter-

tainment of their visitors, while there is assurance that the more suitable of the public buildings of the University will also be placed at their disposal for the same purposes.

The International Congress of Physiology is to meet in Cambridge concurrently with that of Zoology, and certain arrangements will be made in common, though there is no intention of uniting the two Congresses—each of which will retain its distinct organization.

The general arrangements of the Zoological Congress will be made, and from time to time communicated, by the General Committee established at the House of the Zoological Society in London (3, Hanover Square), but the duties of the Reception Committee at Cambridge will be greatly facilitated by the receipt of a reply to this invitation, which they hope may be accepted.

On the receipt of such an acceptance on the accompanying form, further details with regard to local arrangements will be duly forwarded. It is hoped that it will be possible to find rooms in the several Colleges for many of the visitors; but it is necessary to point out that the accommodation afforded within College walls is not suitable for ladies. The Reception Committee will use their best endeavors to find accommodation in lodgings for members who are accompanied by ladies, and it is proposed in due course of time to issue a statement relating to the cost of apartments, railway fares, and other information which will be useful to visitors. Reception Committee: Alex Hill, M.D., Master of Downing College and Vice-Chancellor of the University; Alexander Peckover, Esq., LL.D., F.L.S., St. John's College, Lord Lieutenant of the County; Ernest T. Hooley, Esq., High Sheriff of the County; S. R. Ginn, Esq., Mayor of Cambridge, and others."

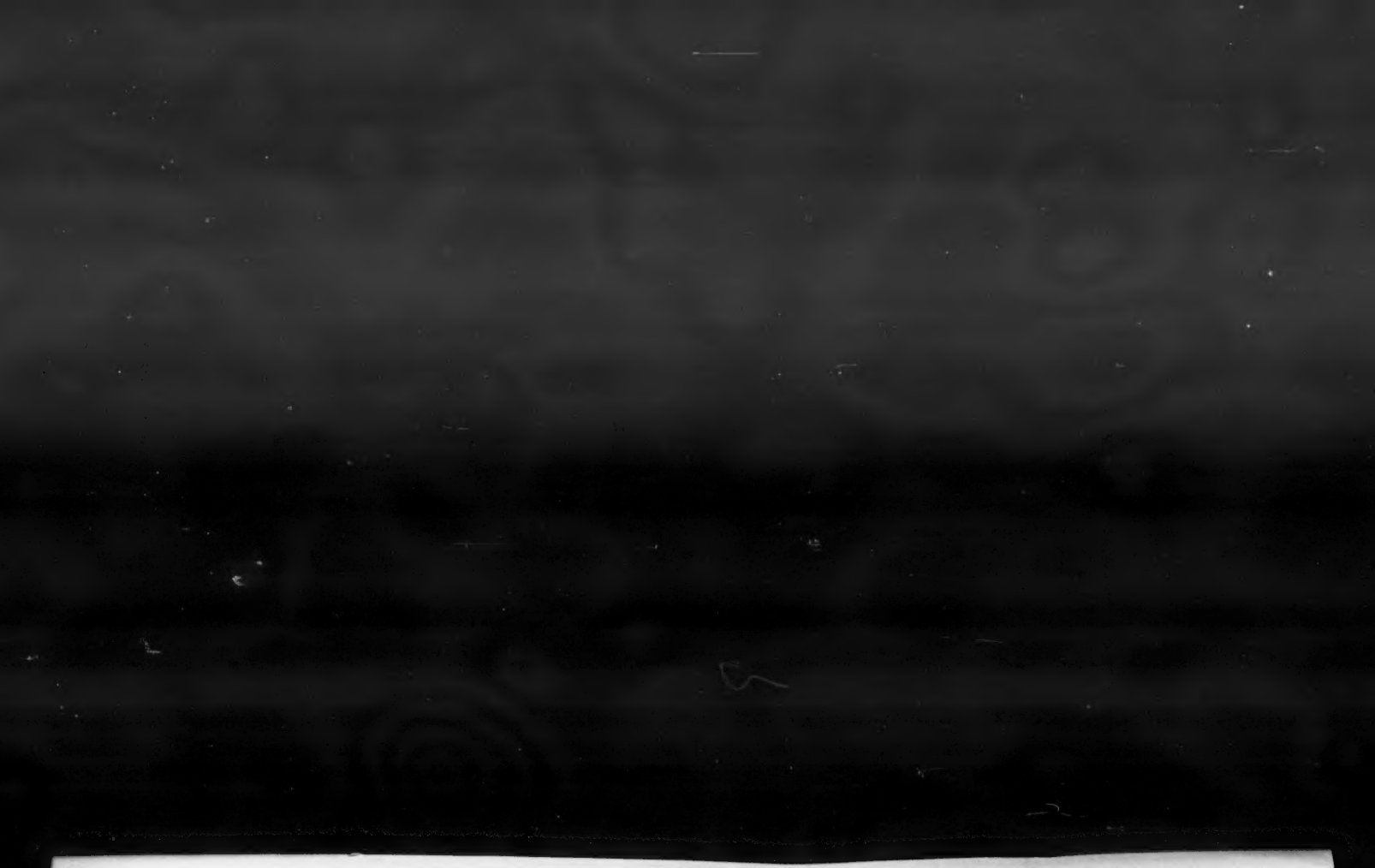
2. *Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1897*, pp. 80. Washington, 1898 (Government Printing Office).—The Report of the Secretary of the Smithsonian just issued gives the usual statement in regard to the year's work of the Institution. In this the description of the National Zoological Park is particularly to be noted. Further, the account of work done in the Astrophysical Observatory. In regard to the latter the following paragraphs are quoted from the report of Mr. C. G. Abbot.

"The work of the observatory during the past year has consisted largely in preparing for publication an account of the research on the positions of absorption bands in the infra-red solar spectrum.

In this report, which was completed in May, 1897, but which, owing to unavoidable delay, has not yet appeared in type, the positions of about 225 absorption lines and bands are determined in deviation and refractive index for a 60° rock-salt prism at the temperature of 20° centigrade. These lines are distributed in the salt spectrum between deviations of 40° 25′ and 38° 45′, corresponding to wave lengths 0·76 μ and 5·20 μ, respectively. The average error probable in the absolute angular deviations of these lines is about 4 seconds of arc, but in their relative deviations measured from the A line in the visible spectrum the probable error averages only about 0·5 seconds of arc, a degree of accuracy even exceeding the anticipations held forth in last year's report. The bolographs from which these results were obtained were taken on exceptionally favorable occasions between October 26, 1896, and January 9, 1897. These bolographs, 13 in number, were selected from among many more, of all degrees of excellence, taken during the same interval.

The forthcoming report contains, in addition to the results above mentioned, an account of the investigations leading up to this research on the infra-red absorption lines; a description of the successive improvements in the instrumental conditions which have rendered possible the present results; a description of the present apparatus and its adjustment; and a discussion of present sources of error and the possibility of future progress. The results of several subsidiary investigations are given, among others being the change of deviation of rock salt with change of temperature, the heat conductivity of rock salt, the effect of diffraction in decreasing the intensity of energy in the spectrum with narrowing slit widths. The report is illustrated with reproductions of photographs and drawings of apparatus, platted curves explanatory of various matters, bolographic curves, and line spectra similar to that here given. With the illustrations, the report is expected to cover about 175 quarto pages."

3. *Studies from the Yale Psychological Laboratory.* Edited by EDWARD W. SCRIPTURE, Ph.D. Volume iv, pp. 141, New Haven, Conn.—This volume contains the results of the excellent research work carried on at the Yale Psychological Laboratory under the charge of Dr. E. W. Scripture. It includes the following articles by Dr. Scripture: Researches on reaction time; Researches on voluntary effort; New apparatus and methods; Elementary course in physiological measurements. Also by C. E. Seashore, Ph.D., the following articles: Influence of the rate of change upon the perception of differences in pressure and weight; Weber's law of illusions. Finally by Alfred G. Nadler, M.D.: On reaction-time in abnormal conditions of the nervous system. Various notes conclude the number.

4. *The Sylvester Medal.*—It is announced that the movement among mathematicians to found some memorial to perpetuate the memory of Professor J. J. Sylvester has finally taken shape in a Sylvester medal for the encouragement of mathematical research. A general international committee has been appointed and the work of collecting subscriptions has gone so far that it is stated that the sum of six hundred pounds is already assured; this does not include American contributions. Those desiring to participate in the movement may send contributions to the treasurer, Lord Rothschild, New Court, St. Swithin's Lane, London, E. C.

5. *Floods of the Mississippi River.*—Bulletin E of the Weather Bureau, United States Department of Agriculture, contains a highly interesting discussion by Park Morrill of the floods of the Mississippi in their various relations to precipitation, drainage, and the special phenomena involved. The great spring flood of 1897 is particularly described. To the 77 pages of text are added 58 large plates. Mr. Morrill is the forecast official in charge of the river and flood service.